SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

1954 Literature Review, Part I—Research Committee

Analytical Methods—Sewage—Radioactivity

Mechanical Air Dispersers—Kalinske

1954 Industrial Wastes Forum

Waste Specifications and Application

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MAY, 1955—VOL. 27, No. 5

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28TH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

AMBASSADOR HOTEL
ATLANTIC CITY, NEW JERSEY

October 10-13, 1955

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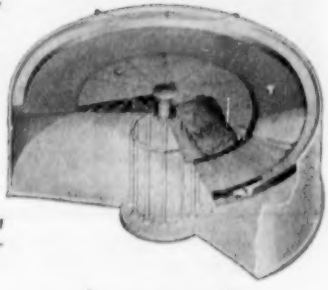

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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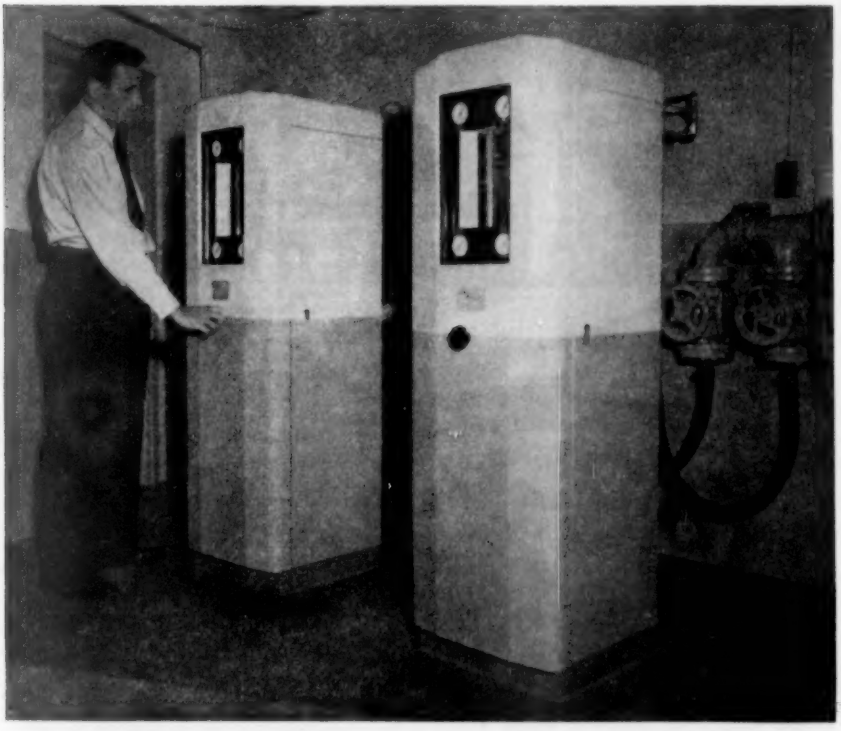

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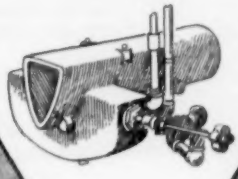

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Maryland-Delaware Water and Sewerage Assn.	Commander Hotel, Ocean City, Md.	May 25–27, 1955
Föreningen För Vattenhygien (Sweden)	Gothenburg, Sweden	June 3–4, 1955
Alabama Water and Sewage Assn.	Univ. of Alabama, Tuscaloosa, Ala.	June 6–8, 1955
New York Sewage and Industrial Wastes Assn.	Hotel Ten Eyck, Albany, N. Y.	June 13–14, 1955
New England Sewage and Industrial Wastes Assn.	Hotel Ten Eyck, Albany, N. Y.	June 13–14, 1955
Institute of Sewage Purification	Brighton, England	June 13–17, 1955
Ohio Sewage and Industrial Wastes Treatment Conf.	Deshler-Hilton Hotel Columbus, Ohio	June 22–24, 1955
Central States Sewage and Industrial Wastes Assn.	Kahler Hotel, Rochester, Minn.	June 22–24, 1955
Pennsylvania Sewage and Industrial Wastes Assn.	Penna. State Univ. State College, Pa.	Aug. 22–24, 1955
Iowa Sewage Works Assn.	Hotel Waukonsa Fort Dodge, Iowa	Sept. 7–9, 1955
Kentucky–Tennessee Industrial Wastes and Sewage Works Assn.	Phoenix Hotel Lexington, Ky.	Sept. 12–14, 1955
Georgia Water and Sewage Assn.	Georgia Inst. Tech., Atlanta, Ga.	Sept. 21–23, 1955
South Dakota Water and Sewage Works Conf.	Brown Palace Hotel, Mobridge, S. Dak.	Sept. 21–23, 1955
Missouri Water and Sewerage Conf.	Connor Hotel, Joplin, Mo.	Sept. 25–27, 1955

TWENTY-EIGHTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
New Jersey Sewage and Industrial Wastes Association
Ambassador Hotel, Atlantic City, New Jersey
October 10–13, 1955

West Virginia Sewage and Industrial Wastes Assn.	Waldo Hotel, Clarksburg, W. Va.	Oct. 19–20, 1955

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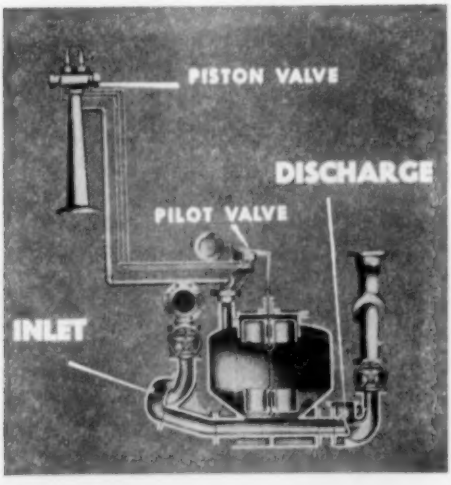

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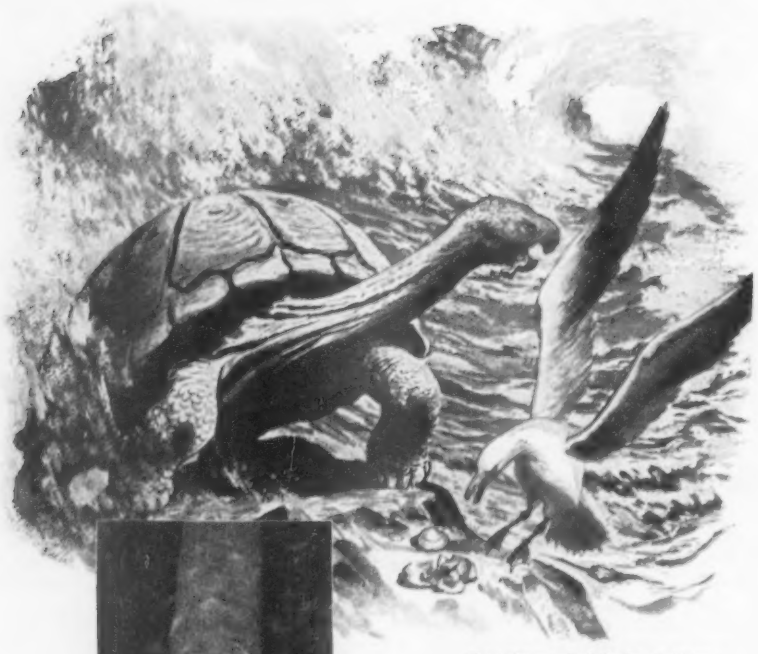

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It often has a life span of 150 years and weighs up to 500 pounds. Once numerous, its ranks became decimated when man discovered it could live for months without food—making it a good source of fresh meat for sailing vessels, especially whaling ships.

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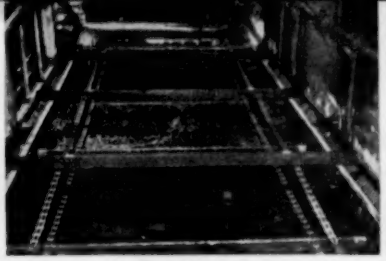

Collector, looking toward influent end from quiescent zone. Slow, uniform speed removes sludge positively with minimum agitation.

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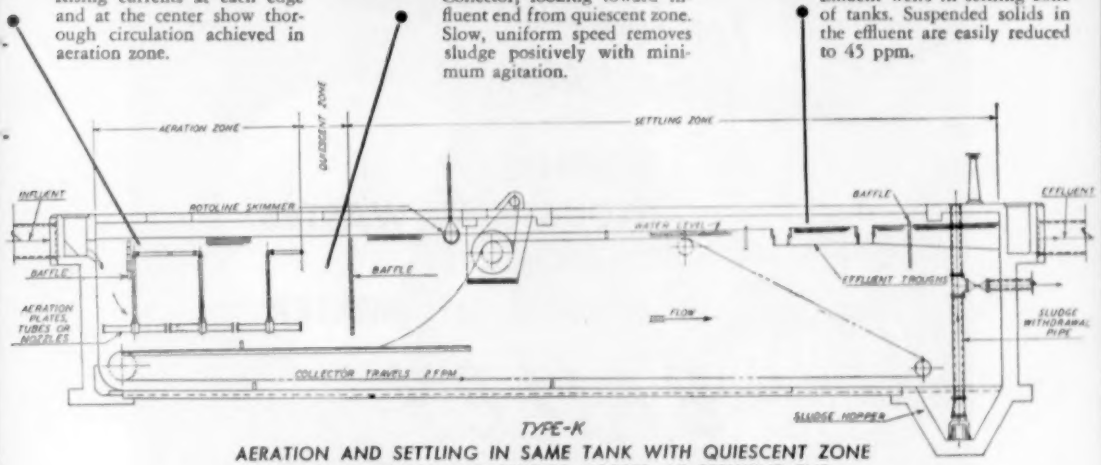

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New LINK-BELT system combines pre-aeration and settling in a single tank

NOT only does the new Link-Belt pre-aeration system cut construction costs by eliminating separate tanks and their connecting piping — it also improves settling tank efficiencies. Violent aeration to prevent settling of heavy solids in aeration zone is unnecessary because they're collected along with the sludge in the settling zone. This, of course, ends the messy job of draining and cleaning the aeration tank manually.

Using only the correct volume of air produces a more gentle agitation. This increases flocculation . . . helps release more entrained gases . . . improves suspended solids settling rate . . . steps up B.O.D. removal. Even when chemicals are added to the sewage, proper mixing rate for maximum flocculation can be used. Sedimentation in aeration zone will not be a problem.

What's more, separated grease is removed immediately in the settling zone by the skimming action of the sludge collector. It is not re-mixed with the sewage in passing from the aeration zone to the settling zone.

For complete information on pre-aeration and other efficient equipment in the broad Link-Belt line, call the Link-Belt office near you. An experienced sanitary engineer — working with you, your chemists and consultants — will help you get the finest in modern sewage, water or industrial waste treatment equipment. 13,342

LINK-BELT COMPANY: Plants: Chicago, Indianapolis, Philadelphia, Colmar, Pa., Atlanta, Houston, Minneapolis, San Francisco, Los Angeles, Seattle; Scarboro, Toronto and Elmira, Ont. (Canada); Springs (South Africa); Sydney (Australia). Sales Offices in Principal Cities.

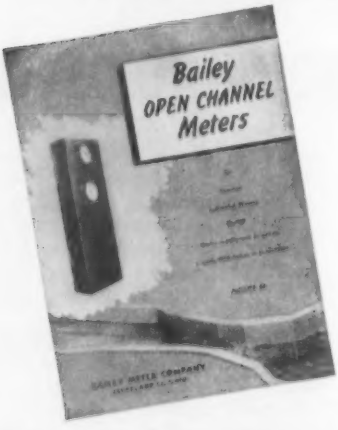
LINK-BELT

SANITARY ENGINEERING EQUIPMENT

For trouble-free, low cost measurement of—

SEWAGE
INDUSTRIAL WASTES
SLUDGE
IRRIGATION WATER

BAILEY
OPEN CHANNEL METERS
Offer These Advantages:



1. Easy to Install
2. Retain Accuracy
3. Self-Cleaning
4. Adjustable Capacities
5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls

Ask for Bulletin 62

MU22

BAILEY METER COMPANY

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METERS and CONTROLS for SEWAGE and WATER

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

Make use of the Unique Advantages of WELSBACH OZONE in Solving Them

If the presence of phenolic compounds in industrial waste is a problem to you and your community . . . and complete destruction is required . . . you should investigate—right now—the economical and dependable solution of that problem by low-cost Welsbach Ozone treatment.

Investigations have shown that chemical oxidation with Welsbach Ozone can provide an *economical* and *complete* answer to the problem of removing phenols from industrial waste.

In addition to its relatively low cost, Welsbach Ozone treatment offers other unique and important advantages:

1. Ozone-phenol reaction is instantaneous. End products are non-toxic. Objectionable tastes and odors do not reappear when water is chlorinated.
2. Welsbach Ozone gives collateral reduction in color, B.O.D. and C.O.D.
3. A Welsbach Ozone plant can be operated on a batch treatment or on continuous basis and can be made fully automatic. Ozonators and treatment vessels require very little space.
4. Welsbach Ozone is generated where it is used. No procurement problems. No freight, storage or materials handling expense.
5. Maintenance costs are negligible. And since the only raw materials needed are electricity and air or oxygen, operating costs are constant and predictable.

. . . but, most of all, Welsbach Ozone is economical, convenient and dependable. Write today for information and, if you wish, indicate the nature of your problem. The Welsbach Corporation, Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

Investigate **WELSBACH OZONE**

LOW COST • DEPENDABLE

ANNOUNCING THE . . . .

TENTH EDITION of STANDARD METHODS FOR THE EXAMINATION OF WATER, SEWAGE AND INDUSTRIAL WASTES

This standard work, prepared jointly by the American Public Health Association, the American Water Works Association and the Federation of Sewage and Industrial Wastes Associations, has been completely rewritten. Practically every method has been drastically revised to include up-to-date methods, technics and materials.

The Tenth Edition has 497 pages of text and 57 figures, as compared with 252 pages of text and 20 figures in the previous edition.

The volume is divided into six parts:

Part I—Chemical Methods for Water

Part II—Examination of Sewage

Part III—Industrial Wastes

Part IV—Examination of Bottom Sludges and Mud

Part V—Bacteriological Methods

Part VI—Microscopic Methods

Bound in water-repellent cloth.

522 pp. Price, $7.50

See page 514 for book review

Published by
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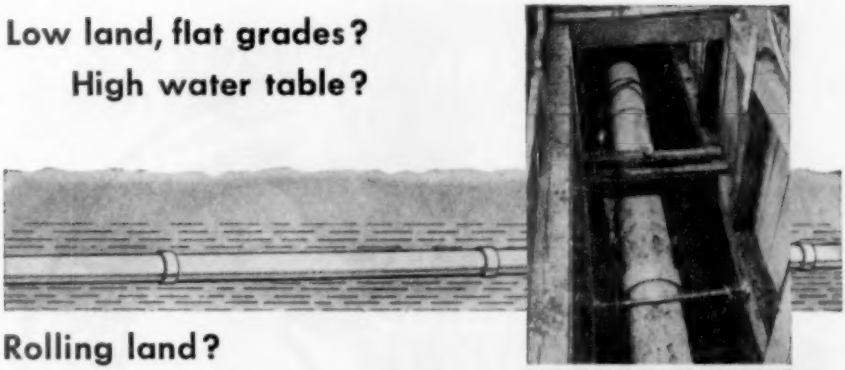
Special price for members of any of the three collaborating organizations if remittance is sent with order, $6.50. Such orders should be sent to organization of membership for verification and forwarding. If remittance is not sent with order, full price will apply.

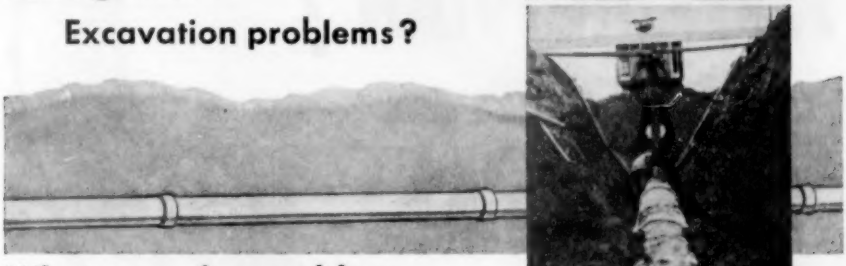
Members of Member Associations should **send their orders to:**

Federation of Sewage and Industrial Wastes Associations
4435 Wisconsin Ave., N. W.
Washington 16, D. C.

Low land, flat grades?
High water table?



Rolling land?
Excavation problems?



Whatever the problem—

Transite® Sewer Pipe

speeds installation, cuts operating costs

In a wide range of conditions, Transite Sewer Pipe and its Ring-Tite® Coupling provide installation and operational *plus-advantages* that add up to important cost savings.

[**Flow Coefficient n=0.010**] For instance, with Transite Sewer Pipe, specified velocity of flow can be attained at a minimum grade. Initial savings may also be reflected in smaller pipe sizes. Its unusually low flow coefficient (n=0.010 derived from the Manning formula) makes this possible. This means less cubic yards of excavation, and may also mean . . . elimination of pumping . . . location of treatment plant at higher elevation . . . lower installation costs especially if in wet or ground-water conditions.

[**Tight Joints**] Where ground water conditions exist (due to a constant water table or during seasonal rains) Transite's Ring-Tite Couplings are *tight* . . . thus treatment-plant dollars are spent to treat *normal* sewage only, not excessive and unnecessary infiltration.

[**Strength**] Made of asbestos and cement, Transite Sewer Pipe is strong and durable. It withstands heavy load stresses, eliminates expensive cradling in many cases. It is available in two strength classifications.

Transite Sewer Pipe is easily handled, quickly assembled and lowered into trench where it adjusts more accurately to line and grade. The Ring-Tite Couplings are easily and quickly pulled, forming tight, flexible joints that *start* tight and *stay* tight.

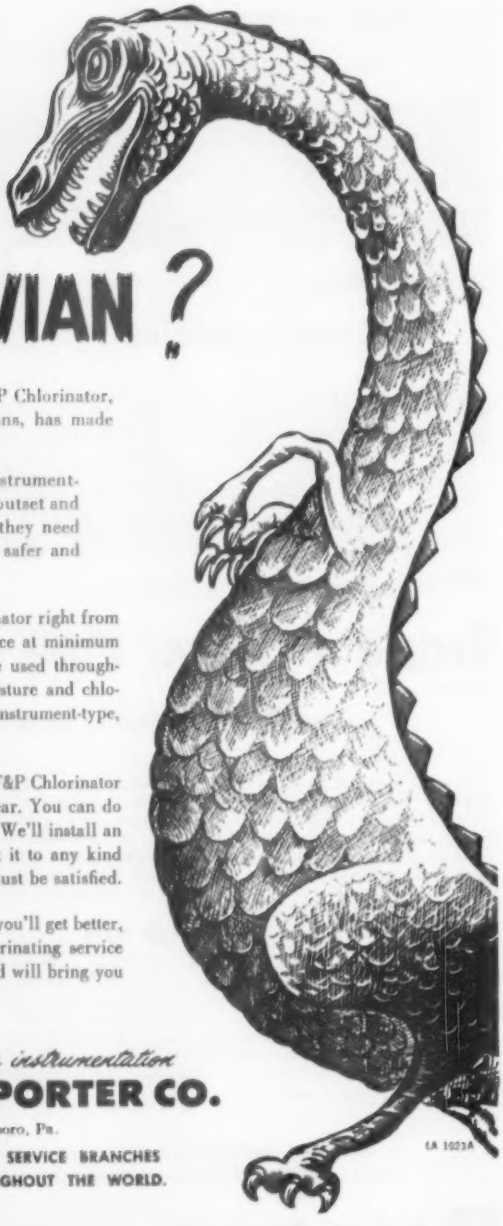
For your copy of TR-94A, the helpful widely used Sewer Design Flow Chart, based on the Manning formula, write Johns-Manville, Box 60, New York 16, N. Y.

Johns-Manville TRANSITE SEWER PIPE

THE PIPE WITH THE TIGHT JOINTS

Are your chlorinators

ANTEDILUVIAN ?



The advent of the *fully mechanical* F&P Chlorinator, without any water trays or water columns, has made all others as dated as the dinosaur.

Now at last you can have modern, instrument-type chlorinators that cost less at the outset and save you money every day, because they need less servicing, less maintenance, are safer and easier to operate.

Fischer & Porter designed their new Chlorinator right from the floor up—to give maximum performance at minimum cost. New corrosion-resistant materials are used throughout. The fibre-glass cabinet is inert to moisture and chlorine. Regulators are modern, mechanical instrument-type, all completely corrosion-proof.

But don't take just our word for it. Let the F&P Chlorinator prove itself—in your own plant for one year. You can do this without risking a penny. We'll install an F&P unit next week. Subject it to any kind of test you can make. You must be satisfied.

You can't lose a thing—and you'll get better, safer, more economical chlorinating service from the first day. A postcard will bring you the facts. Mail it now.

complete process instrumentation

FP FISCHER & PORTER CO.

1155 Fischer Road, Hatboro, Pa.

COMPANY OWNED SALES AND SERVICE BRANCHES STRATEGICALLY LOCATED THROUGHOUT THE WORLD.

Plan NOW to ANSWER THIS SUMMER'S ODOR COMPLAINTS WITH

ORTHOSOLV

The Chlorobenzene that MIXES WITH WATER

For Low-Cost, Easy Use!

Typical Applications of ORTHOSOLV

- Incinerator smoke
- Sewage plants
- New excess-capacity sewers
- Drainage ditches
- Storm sewers
- Sewer breaks
- De-watering of sludge
- Fish market areas
- Land fill refuse disposal
- Refuse cans and trucks
- Dog kennels
- Rendering plants

NOTE: ORTHOSOLV can be safely recommended to private individuals or business concerns for the elimination of odor-causing conditions.

ORTHOSOLV is a concentrated, 100% active material which affords effective odor control even when diluted with as much as *1 part to 100 parts of water!*

It has been used and proven effective in controlling odors from a wide variety of sources in municipalities all over the country.

ORTHOSOLV solutions are *low in cost* and easy to use with street flushers, pressure pumps and hand sprayers.

If you have a particular odor problem, write us giving details and we will be glad to send you our recommendations for controlling it. For FREE LITERATURE and TEST SAMPLES** use coupon below

Other Applications of ORTHOSOLV

Orthosolv is also a highly efficient water dispersible solvent-cleanser for the removal of:

1. Grease and tar from trucks and equipment
2. Oils and greases from concrete floors

Orthosolv can be removed with a water flush or a steam jenny. Orthosolv is safe. It has a high flash point and is not a fire hazard.

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about
the disposal of:

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Grease
Skimmings
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Sludge

Burn them all together in a Nichols Herreshoff furnace.

If you prefer to heat-dry sewage sludge, Nichols Herreshoff furnaces provide the simplest, cleanest and safest of all methods.

Nichols Herreshoff
Multiple Hearth Dryer-Incinerators

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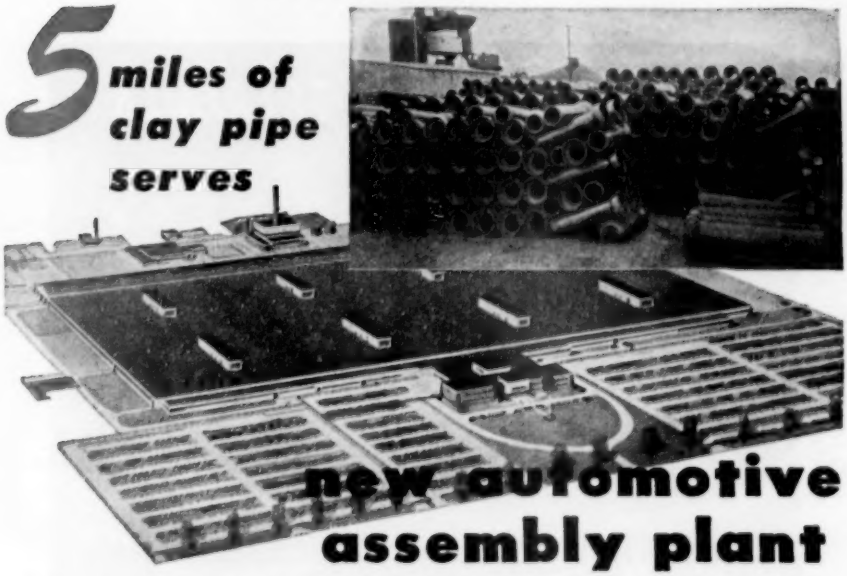
5 miles of clay pipe serves new automotive assembly plant



Ford Motor Company's new assembly plant at Louisville, Ky., will be sewered and drained by Vitrified Clay Pipe in diameters from four to 36 inches. Installation is under the direction of Ford's resident engineer, A. M. Seward. General contractors are Huber, Hunt and Nichols. Sewer contractor is the F. S. Oldt Company, with W. E. Thompson, superintendent and Lamar Cunningham, engineer on the project.

CLAY PIPE FITTINGS MAKE INSTALLATION EASY . . .

A complete line of fittings solves every Clay Pipe problem. This T Saddle, for example, permits additional feeder lines to be connected into trunk lines of equal or larger diameter. Simply make an opening in the trunk line, insert the spigot end of the T Saddle, and seal the joint with mortar or bituminous jointing compound.

In new industrial plants going up all over the country, where sewerage lines *must* be dependable, you'll find Clay Pipe on the job. Installed in the ground beneath equipment that can't be moved, Clay Pipe is the *one* pipe that's sure to give trouble-free service year after year. Heavy surface loads can't cause Clay Pipe to "oval" or squash out. Scalding hot waste can't soften it. Corrosive industrial chemicals can't weaken it. That's why Clay Pipe is guaranteed—barrel, bell, and spigot—for 50 years!

Vitrified CLAY PIPE

NATIONAL CLAY PIPE MANUFACTURERS, INC.

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C-655-1A

COMPLETE LINE to Meet Your Exact Needs

Including many Exclusive Developments

Utilize our many years of experience in the development and manufacture of municipal and industrial waste treatment equipment. Our staff of engineers is ready to cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

Send for Manual 149—Modern Processes and Equipment for Sewage and Industrial Waste Treatment

BIO-ACTIVATION—exclusive system combines best qualities of trickling filter and activated sludge. *Bulletin 259B.*

MECHANICALLY CLEANED SCREENS AND GRINDER—with intermittent automatic control. *Design data in Technical Supplement MS.*

GRIT CHANNELS—exclusive Camp Chamber design and Regulator permit easy and instant variation in velocity. *Design data in Technical Supplement CR.*

GRIT SETTLERS—with conveyor, elevator, and exclusive Hydrowash unit which removes grease and organic matter from grit. *Bulletin 249B.*

GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors. *Bulletin 260B.*

SEWAGE AND SLUDGE PUMPS—horizontal and vertical pumps in wide range of sizes, capacities and heads—including cutting type primary sludge pumps, enclosed impeller type sewage pumps, single vane impeller type sewage pumps and recirculation pumps. **Send for Bulletins.**

SLUDGE COLLECTORS—for rectangular and circular tanks . . . flight type and helicoid cross conveyors . . . sludge valves. *Bulletin 253B and Technical Supplement TV.*

AERATORS—downflow mechanical air diffusion type provides thorough and adjustable oxygenation and circulation of liquor. *Bulletin 265A.*

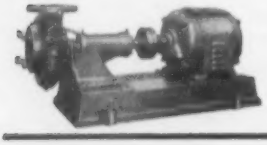
JET AERATION—exclusive method produces an unprecedented rate of oxygen absorption. *Bulletin 265A.*

ROTARY DISTRIBUTORS—reaction and positive drive types with exclusive trouble-free oil seal. *Design data in Technical Supplement RD.*

DOWNFLO FLOCCULATION UNIT—for slow mixing and flocculation of chemicals in sewage treatment processes. *Design data in Technical Supplement PF.*

Send for informative bulletins listed above.

Inquiries on new installations or improvements of existing plants will receive prompt attention.



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Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

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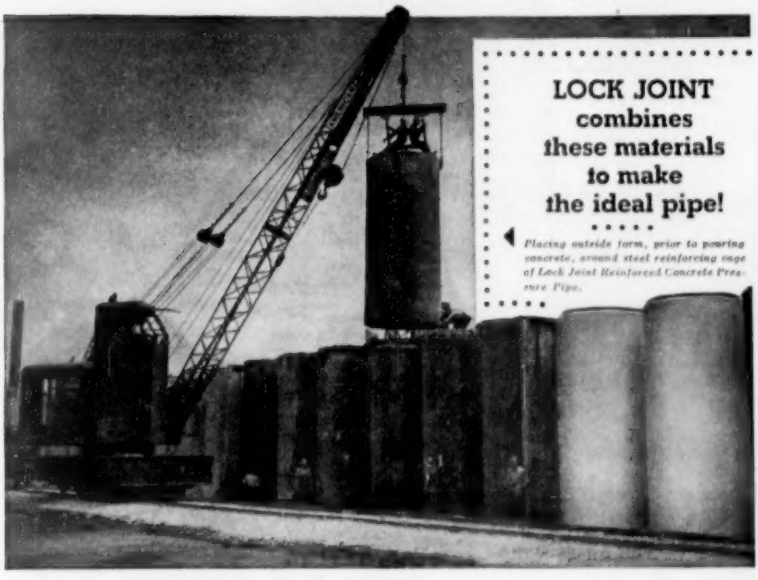
There's no substitute for CONCRETE and STEEL!



LOCK JOINT combines these materials to make the ideal pipe!

Placing outside form, prior to pouring concrete, around steel reinforcing cage of Lock Joint Reinforced Concrete Pressure Pipe.

CONCRETE, with its proven qualities of durability, non-corrosion, resistance to electrolytic action, and high compression strength is combined, by Lock Joint, with steel's toughness, resilience and high tensile strength to make a pipe that retains the best qualities of both—non tuberculance, high structural strength and long life with little or no maintenance. Dense concrete affords complete protection for the quality reinforcing steel. Both materials are carefully calculated to meet your pressure needs with a wide factor of safety. The Lock Joint Pipe Company's Rubber and Steel Joint is extremely watertight and, at the same time, flexible.

For superior strength, carrying characteristics and trouble-free operation, let Lock Joint supply your pipe needs in sizes 16" and larger.

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, N. J.

PRESSURE PIPE PLANTS: Wharton, N. J., Turner, Kan., Detroit, Mich., Columbia, S. C.
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LOCK JOINT *Reinforced Concrete* PRESSURE PIPE

SCOPE OF SERVICES—*Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains 16" in diameter or larger, as well as Concrete Pipes of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.*

THE COILFILTER

Sanitary Engineers' Notebook

MEMO:

Sewage sludges are generally dewatered in one of two ways: (A) On sludge drying beds, (B) By means of vacuum filters. Vacuum filtration is being used more and more, even in small plants, for the following reasons:

1. A much smaller area is required; unsightly and odorous beds are eliminated.
2. Weather does not affect dewatering. A regular schedule may be maintained.
3. Digesters, when utilized, may be smaller, since they do not need to be designed for winter storage.
4. Fresh solids may be dewatered directly, on COILFILTERS.
5. Installed cost of filtration equipment is usually lower.
6. Operating costs are usually lower, when all factors are included.

A vacuum filter installation for sewage sludge dewatering generally consists of the following:

1. COILFILTER
2. Vacuum pump
3. Vacuum receiver
4. Filtrate pump
5. Sludge pump
6. Sludge conditioning tank
7. Conditioning chemical feeders and tanks
8. Cake handling equipment

Each of these components will be discussed in future Memos in the SANITARY ENGINEERS' NOTEBOOK.

KOMLINE-SANDERSON ENGINEERING CORPORATION
PEAPACK, NEW JERSEY

Manufacturers of COILFILTER *sludge vacuum filters*

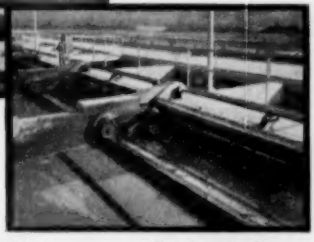
CLEVELAND Chooses REX®

Cleveland Southerly Sewage Treatment Plant.

Havens and Emerson, Consulting Engineers.

W. E. Gerdel, Superintendent.

18 power driven chain and scraper skimmers.



Six primary tanks 50' wide x 126' long.

OVER 2500 REX CONVEYOR SLUDGE COLLECTORS IN OVER 750 CITIES AND INDUSTRIES...

WHAT BETTER PROOF OF REX SUPERIORITY?

Yes, over 750 cities and industries rely on Rex® Conveyor Sludge Collectors for efficient, dependable and economical operation. These precision-engineered sludge collectors are applicable for all types of sludge-handling or surface-skimming conditions in either sewage, water or industrial waste treatment application...no application is too large or too small...and each receives the full benefit of Rex Engineering.

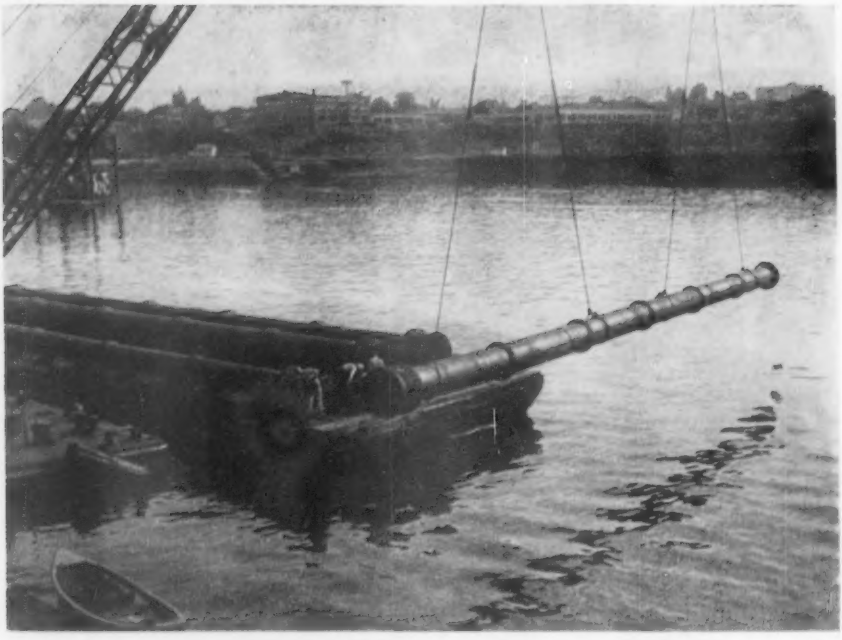
Here are some of the outstanding time-proven features of Rex Sludge Collectors.

- Balanced Equipment Design—design proportionate throughout.
- Rex Z-Metal Chain and Attachments—corrosion and wear resistant.
- Self-Aligning Bearings—easy to install. Compensate for tank irregularities...prevent accumulation of settled solids.
- Offset Split Drive Sprockets—eliminate bulky cantilevered brackets. Easy to replace.
- Centralized, Hardened Wearing Shoes—eliminate splitting strains on wooden scraper flights. Means longer life, lower maintenance.
- Double-Life Sprockets—chain engages only every other sprocket tooth.
- Drive Unit—compact, totally enclosed. Shear pin protection. Jaw clutches provided where independent operation is required.
- Sub-Assemblies—shop assembly of drive units and shaft assemblies assure proper alignment and fit.

MAKE SURE YOU WILL BE THE NEXT ONE to profit from Rex Design and Rex Quality. Get all the facts on Rex Conveyor Sludge Collectors. Call your nearest Rex Sanitation Engineer or write for Bulletin 49-9. Chain Belt Company, 4606 W. Greenfield Ave., Milwaukee 1, Wisconsin.

REX® CHAIN BELT COMPANY

District Sales Offices in all principal cities



AMERICAN Cast Iron Pipe

For Every Service Condition

RIVER CROSSINGS and other underwater pipe installations present no problems when you select AMERICAN river crossing pipe. Designed to meet the severe requirements of submarine pipe lines, AMERICAN Molox Ball Joint river crossing pipe provides for expansion and contraction of the pipe line and at the same time is locked against separation.

AMERICAN river crossing pipe's rugged construction enables it to be pulled across streams with cables or laid direct from a barge or bridge. The above illustration shows parallel 30″ and 42″ AMERICAN Double-X Mechanical Locked Joint pipe lines combined with Molox Ball Joint double hubs, being laid under the Willamette River in connection with a sewerage project at Portland, Oregon. The river depth ranged from 30 to 70 feet and the lines were each 1500 feet in length.

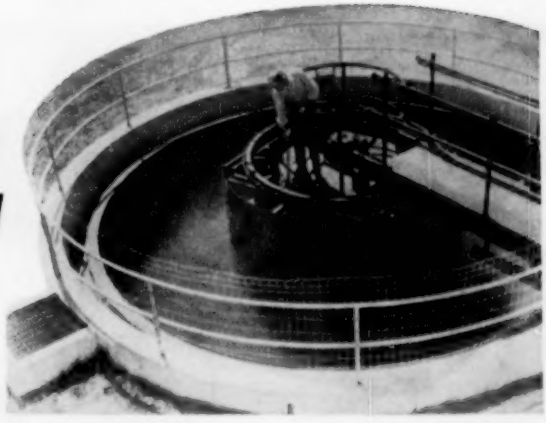
Whether it be underwater or overland, refer your next piping job to AMERICAN CAST IRON PIPE. Let us assist you by taking off lists of material and submitting prices on pipe and fittings. Consulting with us imposes no obligation.

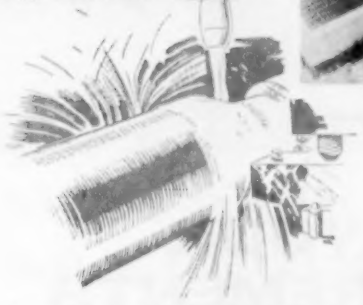
AMERICAN

AMERICAN CAST IRON PIPE CO. 50 YEARS BIRMINGHAM, ALABAMA

1905 - GOLDEN ANNIVERSARY - 1955

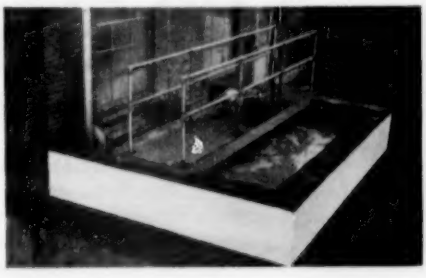
Disposal of metal finishing wastes–as easy as 1-2-3!





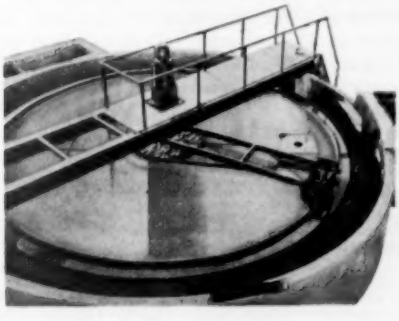
Treatment of pickle liquors, detergents, plating solutions, coolants and rinse waters is rapid and economical when you use INFILCO equipment. One or more of the units shown here will provide a permanent solution for your waste disposal problem.

1. CYCLATOR® Clarifier: A high-capacity unit for removing metals, soluble oils and suspended solids, and for pH adjustment.



2. VORTI-MIX® Circulator: For primary treatment of plating wastes which contain chromates and cyanide. Also applied to pickle liquor neutralization and cracking of oil emulsions.

3. PRIMARY CLARIFIER: For recovery of oil and removal of settleable solids when two stage treatment is required.



The proven success of this equipment in the metal finishing industry is your assurance of satisfaction. See your consulting engineer or write for complete information.

INFILCO INC.
921 South Campbell Ave., Tucson, Arizona
Offices in principal cities in North America

INFILCO

The one company offering engineered equipment for all types of water and waste processing—coagulation, precipitation, sedimentation, flotation, filtration, ion exchange and biological treatment.

FOR ALL YOUR ALUM REQUIREMENTS

Specify Dependable General Chemical

THE CHOICE OF WATER OFFICIALS AMERICA OVER – General Chemical Aluminum Sulfate is the alum used in producing crystal-clear, sparkling water in so many leading American municipalities and industries. It has consistently met the most rigid specifications for more than half a century . . . is also the most widely used coagulant for the removal of turbidity, organic color and other impurities from water.

PRODUCTION FACILITIES ALL OVER THE MAP – Wherever you are, you are near a General Chemical plant producing dry or liquid alum for water processing . . . 20 different primary sources in every section of the country. In emergencies . . . at all times . . . public works officials have found they can count on General Chemical for adequate supplies and prompt deliveries of this *preferred* water-processing alum.

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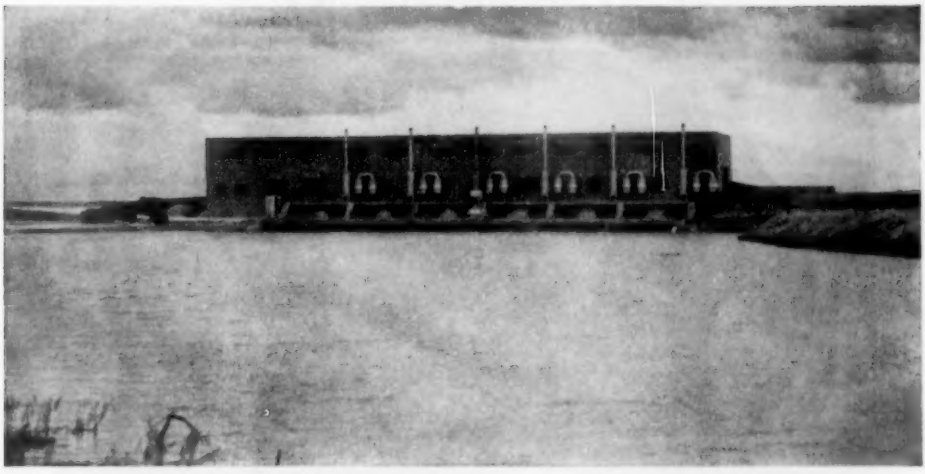

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Located at the southern tip of the lake, the station houses six of the world's largest pumps . . . built by Fairbanks-Morse . . . powered by Fairbanks-Morse Opposed Piston Diesel Engines.

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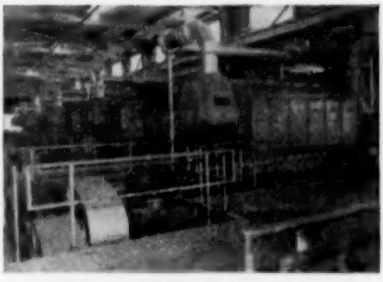
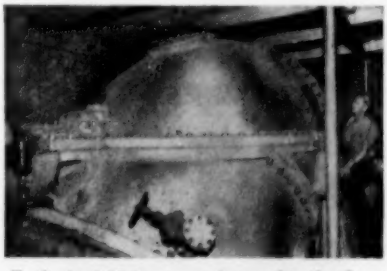


Six 1600-hp. Fairbanks-Morse Opposed Piston Diesel Engines insure uninterrupted power for the big pumps, especially during storm periods when they will be most urgently needed.



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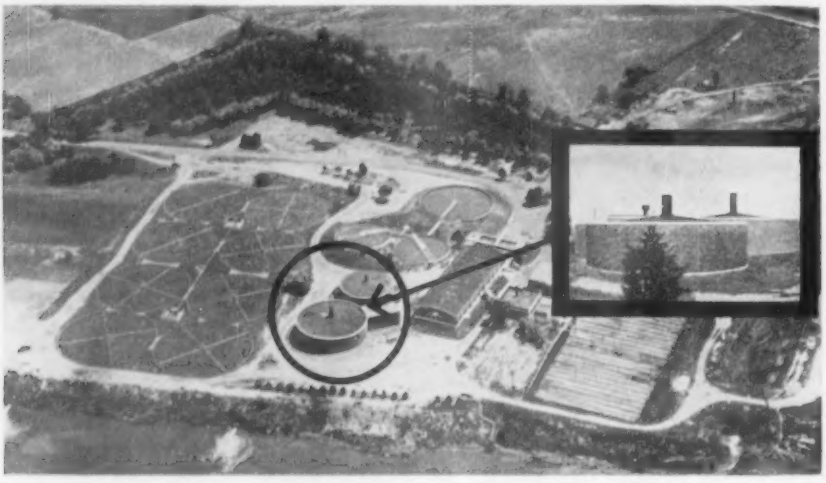
Circled area shows 2PFT Floating Covers—long building contains 5 rectangular PFT Floating Covers



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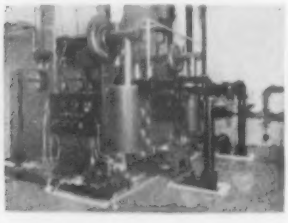

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 27 | **May, 1955** | **Number 5**

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1954 Literature Review

A CRITICAL REVIEW OF THE LITERATURE OF 1954 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

By H. Heukelekian, *Chairman*, D. E. Bloodgood, N. S. Chamberlin, G. P. Edwards, M. B. Ettinger, I. Gellman, C. Henderson, R. D. Hoak, R. S. Ingols, P. W. Kabler, M. Katz, R. R. Kountz, R. Manganelli, G. N. McDermott, P. H. McGauhey, W. A. Moggio, W. A. Moore, H. E. Orford, R. C. Palange, C. M. Palmer, G. A. Rohlich, L. R. Setter, D. B. Smith, C. M. Tarzwell, H. A. Trebler, E. C. Tsivoglou and L. W. Van Kleeck

Committee on Research, Section A, Federation of Sewage and Industrial Wastes Associations

This first of two sections of the review deals with analytical methods, sewage and radioactivity. The second section, dealing with industrial wastes and water pollution, will be published in the June 1955 issue of This Journal.

ANALYTICAL METHODS

Biochemical Oxygen Demand

Lee and Oswald (54), from a comparative study of the Warburg and dilution methods for determining B.O.D., reached the following conclusions:

1. The ultimate first-stage L averaged about 15 per cent higher for the Warburg method, although the reaction rate k was approximately the same for both methods using both sterile and fresh domestic sewage.
2. The use of frozen seed for both methods was not entirely satisfactory and needs further study.
3. The relatively small amount of "Standard Methods" dilution water used in the Warburg method is not sufficient to buffer the mixture at the desired pH.
4. When using sterile wastes the Warburg method is particularly sensitive to the seed and nutrient present.
5. The Warburg method is not applicable to large numbers of daily routine B.O.D. determinations.
6. Maintenance cost for Warburg method is approximately 10 times that of the dilution method, although the degree of technical ability required by both methods is about the same.
7. In application to practical problems, it is concluded that the dilution method is the most practical.

Bryan and Rohlich (11) in determining the B.O.D. of sewage used sodium chlorate as the oxygen source and determined the increase in the chloride content at stated incubation times. The chlorate must be in excess of that required for oxidation of the organic material present and atmos-

pheric oxygen must be excluded. A 5-day incubation period was found to be sufficient if the B.O.D. of the waste was less than 100 p.p.m., although a 10-day period is recommended. If the seed used had previously been acclimated to chlorate reduction, the time required for rapid oxidation to occur in the sample was reduced.

The chlorate oxygen demand was independent of the amount of chlorate used as long as it was in excess and its concentration was not inhibitory to the organisms present. The precision of the B.O.D.'s obtained by this method was as good as with the "Standard" dilution method.

Meissner (65) determined the B.O.D. oxygen consumed value and chlorine and bromine number of a great many pure compounds.

Jasewicz *et al.* (46) found that borax could be used for the preservation of dairy waste samples for B.O.D. and C.O.D. determination. However, the dilutions of the incubated samples must be such that the borax concentration is less than 1,000 p.p.m., above which inhibition of biological action was noticed. It also was found that the added borax had no effect on the C.O.D.

In a study of the nitrification phase of the B.O.D. reaction, Buswell *et al.* (12), using cultures of *Nitrosomonas* sp. in dilution water containing ammonia, found that the oxygen uptake was related to the multiplication of the organisms and independent of substrate concentration. This also has been shown by others in studies of the carbonaceous B.O.D. During a 5-day incubation period, there were different rates of oxygen uptake, including (a) that associated with cell growth and (b) that associated with the resting or dying culture. In neither case was there a simple relationship between oxygen consumption and substrate concentration. Horton (43) measured the oxygen uptake in the activated sludge system used in the treatment of dairy wastes by means of the oxidation-reduction potential developed. By plotting the oxidation-reduction potential against time, hourly variation in the metabolic activity of the organisms present could be followed and the process controlled. The rate of change in the oxidation-reduction potential was found to be related directly to the change in dissolved oxygen and thus to the B.O.D.

Bouquiaux (8) presented methods for determining the proper B.O.D. test dilutions to set up for assuring a 5-day depletion between 40 and 60 per cent. The equations are worked out by assuming the presence of 8 p.p.m. O_2 in the diluted sample and relating this to the oxygen consumed from cold permanganate in 3 min. From tables in the original publication the necessary dilutions can be determined assuming a theoretical B.O.D. of 100. Horne (42) also presented a graphical system for determining the dilutions to be set up to cover the necessary range of oxygen depletions.

In the study of textile wastes, Northrup (71) compared the oxygen consumed values obtained with 0.0125 and 0.125N $KMnO_4$ with the 5-day B.O.D. The O.C. values obtained varied widely, depending on the experimental conditions used. It was concluded that the B.O.D. was a more satisfactory parameter with such wastes. Kaufman (47) also studied the B.O.D.-O.C.D. (oxygen consumed by dichromate) relationship on a pharmaceutical waste. Despite the fluctuation in the concentration of the components of the raw waste, the B.O.D.-O.C.D. regression curve gave a high degree of correlation. With the treated waste it was necessary to use the percentage treatment efficiency of the previous week to obtain a factor $\Delta = 1 - \text{B.O.D.}/\text{O.C.D.}$ when the formula $\text{B.O.D.} = \text{O.C.D.} - \Delta\ \text{O.C.D.}$ and accurate B.O.D. estimate could be made from the O.C.D. results. This eliminated the necessity for B.O.D. de-

terminations except for occasional checks. The curve obtained is only valid for this particular waste; for other wastes, individual empirical determinations are necessary.

Confusion has existed in the literature on the toxicity of many common ions to the B.O.D. test. The Research Committee (77) obtained data on the toxicity of both mercury and chromium. The data for Hg indicates a slow increase in toxicity for 0.02 to 0.20 p.p.m. with complete bacteriostasis beyond 0.20 p.p.m. Chromium is much less toxic than mercury, with the Cr^{+3} ion being more toxic than the Cr^{+6} ion. The concentration of organic material present affects the toxicity of both mercury and chromium.

Oxygen Consumed

A method for continuous measurement of the organic matter contained in the effluent from an industrial plant was developed by Kieselbach (50). The concentration of organic carbon is recorded directly in p.p.m., the limit of sensitivity being about 1 p.p.m. The apparatus will respond to a change in the organic content of the waste sample in 10 min. The determination consists of filtration of the sample, precipitation of any carbonate present, oxidation of the organic carbon with dichromate in concentrated H_2SO_4, stripping and purification of the resulting CO_2, and measurement of the CO_2 formed. Although some phases in the operation of this apparatus remain to be improved, it is expected that a fully automatic analyzer is entirely practical. Gertner and Ivekovic (34) determined the percentage of oxidation of a number of organic compounds, using $K_2S_2O_8$ as the oxidizing reagent. The compounds studied included aldehydes, sugars and amino acids, the oxidation of which ranged from 96 to 104 per cent of theoretical. To the acidified sample, 10 ml. of 10 per cent $AgNO_3$, 100 ml. of 10 per cent $K_2S_2O_8$, and 50 ml. of 9N H_2SO_4 are added and the mixture is heated to 80°. In some cases, it is necessary to add a second portion of $K_2S_2O_8$. The CO_2 obtained is absorbed in weighed ascarite tubes.

Oxidation of the organic carbon in sea water was carried out by Kay (48) using a wet combustion procedure. The sample was electrically heated at 130° in a completely closed vessel in the presence of H_2SO_4 and K and Ag dichromates. A current of O_2 carries the evolved gases through aqueous KI, over metallic Sb, and through a combustion tube where the CO is oxidized on a Pt contact and the SO_2 absorbed by Ag. The CO_2 is absorbed by standard $Ba(OH)_2$ and the excess $Ba(OH)_2$ titrated with HCl. The access of air is prevented in the closed system.

Dissolved Oxygen

Briggs *et al.* (9) devised an apparatus for the continuous automatic measurement of dissolved oxygen in water. The ordinary Winkler reagents are used and the optical density of the liberated iodine is measured. To correct for any turbidity present, the iodine is destroyed by bisulfite and the optical density again determined. The difference between the two readings gives the amount of dissolved oxygen present. Ippen and Carver (45) used both the dropping mercury and rotating platinum electrodes for the continuous measurement of dissolved oxygen. Results with either electrode are claimed to compare with those by the Winkler method. The rotating platinum electrode is preferable as it was less affected by turbulence in the water stream. Todt *et al.* (96) also studied the electrochemical determination of dissolved oxygen and were able to place it on a continuous recording principle. These authors investigated the effects of electrolyte concentration, hardness of the water, surface area and type of electrodes on the D.O. determination. They found

that the upper limiting values for NaCl was 200 p.p.m., for $CaCO_3$ hardness 360 p.p.m., and electrode size about 0.1 sq. cm.

Ohle (73) measured D.O. by a galvanic cell with gold and zinc electrodes incorporated in an oxygen plummet. To offset diffusion current variations due to electrolyte concentrations between 40 and 14,000 p.p.m., a variable resistance ammeter was connected to the plummet. pH variations between 3 and 11 and hardness up to 120 p.p.m. $CaCO_3$ have no effect. At a higher hardness diffusion current decreased with time, due to sealing. D.O. profiles of four different lakes showed about 5 per cent deviation from the Winkler Method.

Egalon and Vanhille (24) used a somewhat different approach in the continuous recording of dissolved oxygen concentrations. A stream of specially purified N_2 was used to sweep the O_2 from the sample. The O_2 was then converted to CO_2 by passage over carbon at 570°. The CO_2 was absorbed in a NaOH solution, the electrical conductivity of which is continuously measured. Hoover *et al.* (41) found that the magnetic oxygen analyzer had many useful applications in water supply and waste treatment processes.

Banks (3) used an absorptiometric method for determining D.O. which he claims is just as accurate as the dead-stop end point. To the sample he added $MnCl_2$, alkaline-iodide, and 18N H_2SO_4, mixing after the addition of each reagent, the floc being permitted to settle somewhat before adding the H_2SO_4. An aliquot was buffered with an NaOAC solution, followed by the addition of a 3,3'-dimethylnaphthidine solution. The optical density of the developed color is measured. A calibration curve was made using increments of 0.001N I_2 solution and the color developed as for the sample. Another colorimetric method, developed by Loomis (59) used oxidation of a reduced indigo-carmine solution by the D.O. present. The reaction was carried out in a tuberculin syringe adapted for direct use in a spectrophotometer. Advantages claimed for the method are use of small samples (0.5 ml.) and the short time necessary to make the analysis (1 min.) Stone and Sigal (91) determined D.O. in waters containing nitrite by means of an acid-chromous reagent. The nitrite was first destroyed and the sample then added to a specially designed apparatus enclosed in a constant-temperature jacket. The acid-chromous reagent was added and the excess Cr^{++} destroyed with standard KIO_3 solution. KI was then added and the liberated iodine titrated using a starch end point. The total number of equivalents of Cr^{++} less the equivalents of IO^-_3 used up is equal to the number of equivalents of O_2 in the aliquot taken. The accuracy and precision are claimed to compare with other standard methods. Determination of D.O. in waters containing sulfite waste is subject to gross errors by the Winkler procedure. Levine and Williams (56) used a polarographic method and studied the effect of pH, sulfite waste concentration, and the operating potential on this determination. With increasing waste concentrations the diffusion current was reduced and the oxygen waves shifted to more negative potentials. These effects were at a minimum at low pH values. Current-time measurements at a given potential showed that the sulfite waste had an "immediate oxygen demand" only in alkaline solution. D.O. can be measured by this method within the limits of experimental error in waters containing up to 3.0 per cent sulfite waste.

Freier (29) used a colorimetric modification of the Winkler method to determine D.O. in boiler feed waters. The manganic ion dissolved in phosphoric acid produced quantitatively a yellow color with o-tolidine.

Organic Compounds

In the analysis of industrial waste samples the determination of oil is quite often important. Beaudoin (5) used a simplified method for the determination of the oil content of waste waters high in oil. From the sample (1 gal.) a portion of the water was drawn off and a weighed amount of unspecified solvent was added. After shaking, an aliquot of the solvent was removed in a tared flask and weighed, the solvent was evaporated off, and the flask plus oil reweighed. From the total amount of solvent added, the oil in the aliquot, and the solvent in the aliquot, the total oil present can be calculated.

Taubert (94) reviewed critically seven methods for determination of phenols. These included the 4-aminoantipyrine and the infrared procedures. Schmaugh and Grubb (81) made use of the ultraviolet absorption bands of phenols in their determination in waste waters. The sample was first extracted at pH 12 with CCl_4 to remove any oil present. The pH was then lowered to 5 and extracted with tri-butyl phosphate to recover the phenol as a concentrate. The pH of a portion of this extract was raised to 12.0 and the absorption at 301 mμ. measured. The absorption also was measured in that portion held at pH 5.0. By comparing the absorption at the two pH values, the amount of phenol present is calculated.

Due to the increased production of synthetic detergents their determination has been the subject of numerous studies. So far, the methods developed have been confined mostly to the determination of the anionic type of compounds. Edwards and Ginn (23) used the two-phase titration method of Barr modified by adjusting the pH to 7.0 to 7.5 to eliminate interference due to soaps and proteins. Addition of the sodium salt of ethylenediaminetetraacetic acid avoided errors due to the presence of Ca and Mg. Concentrations of NaCl and Na_2SO_4 up to 1,000 p.p.m. are claimed not to affect the results. The effects of NO^-_2, NO^-_2, SCN^- and compounds present in urine are also eliminated. Either bromophenol blue or phloxine can be used as indicators in the titration. Both of these give straight-line curves, but with different slopes. Kay (49) modified the methylene-blue method of Evans by extracting the color formed at two pH values and extrapolating the curve back to a pH of -2. The interference effects of CNS^-, NO^-_2 and the compounds present in urine were minimized somewhat, but not eliminated by this procedure. Loomeijer (58) used a protein-cresol purple complex to determine many types of anionic detergents. Within limits the amount of dye released from the complex was proportional to the concentration of detergent present. A continuous recording method for determination of surfactants in water and sewage was reported by Hettche (37). A ring tensiometer incorporated in an automatic sampling and recording device measuring surface activity every 3 min. detected 0.007 p.p.m. of a household detergent. Use of nonionic detergents has been limited and few methods for their determination have been advanced. Gallo (33) used $(BiSCN_6)K_3$ as a reagent in determining polyhydroxyethylene compounds. This compound forms a yellow precipitate with the detergent which is soluble in excess of the reagent. Using paper chromatography, the various polyhydroxy-ethylene compounds give high Rf values in about the same range. These compounds are not adsorbed on Al_2O_3 and so it was feasible to separate the nonionic detergent from other substances present in the solution. Another approach to the determination of nonionic detergents, by Stevenson (89), precipitated the detergent with phosphomolybdic acid and subsequent measurement of the

optical density when the precipitate was dissolved in a suitable solvent. It is claimed that 10 μg. of the detergent can be detected in 10 ml. of sample. In the past the cationic detergents have been difficult to determine and adequate methods are few. Fogh *et al.* (26) based determination of cationic detergents on the fact that cetylpyridinium chloride (I) will change the color of bromcresol purple from violet to blue at pH 8.2. They were able to determine (I) in concentration from 0 to 25 γ per ml. Neither Ca, Mg, Fe^{++}, Fe^{+3} nor Cu cause interference when their concentrations do not exceed 1 per cent. The tendency of (I) to be adsorbed on the glass or to concentrate in the froth when the solutions are shaken was noted. In the former case, the loss may be as high as 70 per cent.

Norton *et al.* (72) determined uric acid in fresh and sea water, also in water containing organic material. The method was based on the reaction of uric acid with arsenophosphotungstic acid in the presence of cyanide ion. Ethylenediaminetetraacetic acid was used as a buffering and complexing agent. The optical density of the blue color developed was measured at 890 mμ.

In the determination of polynuclear hydrocarbons in sewage sludge Wedgewood and Cooper (98) extracted the dry sludge with acetone for several hours. The acetone was removed by evaporating in the presence of cyclohexane. The cyclohexane solution was chromatographed and the eluate examined spectrophotometrically. In the case of effluents, a 1-l. sample was first extracted with $CHCl_3$ and the extract evaporated to dryness. The residue was dissolved in cyclohexane and chromatographed on alumina. Fractions that contain particular hydrocarbons can be combined and concentrated if necessary. It was estimated that pyrene in a concentration of 1 p.p.b. was present in effluents.

Nitrogen Compounds

In some cases it is inconvenient to carry Nessler reagent in the liquid form for field work. Batmanova (4) made up this reagent in a dry form. This was done by triturating KI (1 part) and HgI_2 (2 parts), the mixture being put up in ampoules containing 20 to 30 mg. One ampoule is mixed with a solution containing a 0.1-g. tablet of KOH dissolved in 1 ml. of distilled water. Five drops of this Nessler reagent was used for a 10-ml. water sample.

McKenzie and Wallace (62) in a detailed investigation of the factors involved in the Kjeldahl determination of nitrogen, found that the optimum temperature for digestion was 380° to 390° in a solution containing 1g. K_2SO_4 per ml. of H_2SO_4. The use of Se and $CuSo_4$ as catalysts were not as effective as was that of HgO, and with the former a loss of N_2 occurred. The addition of 50 mg. of HgO shortened the clearing time of the digestate and the recovery of N_2 was quantitative after a further 15 min. of digestion with the organic nitrogen compounds tried. These compounds included trytophan, which is difficult to break down. Addition of $Na_2S_2O_3$ to the NaOH used for liberation of the ammonia was more advantageous than using sulfide. Use of 2 per cent H_3BO_3 for receiving the liberated ammonia, together with using methylene blue-methyl red indicator in the titration is recommended. Yuen and Pollard (100) also advocated the use of methylene blue-methyl red indicator for titrating liberated ammonia. They pointed out that the concentration of H_3BO_3 is important in that the transition color change of the indicator decreases in sharpness with increase in H_3BO_3 concentration. Ten ml. of 1 per cent H_3BO_3 will be sufficient for nitrogen concentration up to 5.0 mg.

Metallic Ions

Various modifications (25)(92)(35)(87)(31)(30) of the original Schwarzenbach method for the determination of total hardness and the differentiation of Ca and Mg hardness have been published during the year. Phosphate has been one of the interfering ions in the determination of total hardness by titration with the Na salt of ethylenediaminetetraacetic acid. Collier (16) proposed a method for eliminating such interference. An aliquot of sample containing not more than 10 mg. each of Ca and Mg was made acid with HCl. To this mixture 10 ml. of 20 per cent Na_2MoO_4 and 20 ml. of BuOH – $CHCl_3$ (1–1) were added. After shaking, the bottom layer was drawn off and the aqueous layer extracted twice with 20 ml. and 10 ml. of the same solvent. Ca and Mg is determined on the clear, aqueous portion by titration with ethylenediamitetraacetic acid. Melocke and Shapiro (66) determined Ca and Mg by means of a rotating silver disk electrode in which the range of concentration was 0.1 to 30 p.p.m. An average standard deviation for Ca from 4 to 10 per cent and for Mg, 2 to 10 per cent is claimed. The method also is said to be more rapid and sensitive.

Determination and differentiation of Fe^{+2} and Fe^{+3} has been a problem not only to the industrial waste chemist but to the waterworks operator as well. Shidlovskaya-Ovchinnikova (84) studied the stabilization of Fe^{+2} in the presence of Fe^{+3} and found after the addition of an acetate buffer (pH 4.0) to a water sample containing both valence states of iron that the differentiation could be made even after 30 days of storage. Orthophenanthroline has been used extensively in the determination of iron in potable waters and industrial waste waters. Smith *et al.* (86), however, found that 4,7,diphyenyl-1,10-phenanthroline was more sensitive and was applicable to the determination of 1 to 10 γ of iron in a 100-ml. sample. The Fe^{+2} complex can be extracted by isoamyl alcohol. Standards are stable for months if adequately protected from sunlight. The maximum absorption of the iron complex obtained by the use of this reagent occurs at 533 mμ. Buydens and Muylle (13) made a comparative study of five methods for the determination of iron in water as follows:

1. Thioglycolic acid.
2. Na, 1, 2-dihydroxy-3,5-benzenedisulfonic acid.
3. Thiocyanate.
4. *o*-phenanthroline.
5. 2,2-bipyridine.

Methods 2 and 3 gave the most reproducible results; in method 1 the pH could be adjusted with NH_4OH without the use of a buffer. Aconsky *et al.* (1) found that a dilute solution of $K_2Cr_2O_7$ possessed the same optical properties as the color developed in the determination of iron by the thiocyanate method.

The determination of copper was investigated by Delaney (21). He found that bis-(2-hydroxyethyl) dithiocarbamate possessed several distinct advantages over sodium diethyldithiocarbamate as used in "Standard Methods." The new reagent can be prepared by the mixing of two stable reagents and the colored complex formed is water-soluble and no stabilization is necessary. Iron in concentrations as high as 20 p.p.m. could be eliminated by addition of a pyrophosphate solution.

Chizhevskaya (14) used a polarographic method for the determination of Zn in industrial waste waters. The method consists essentially of a double evaporation of the sample with HCl and HNO_3, followed by ashing. The ash is extracted with either $CaCl_2$ or NaCl solution (30 per cent) and the Zn content determined. He claims a sensitivity of about 5 γ Zn per ml.

In the determination of Zn by the $K_4Fe(CN)_6$ method, H_2SO_4 has been used in the acidification step. Petzold (75) found that in the presence of ammonium salts high results were obtained for the Zn content. By substituting 2 ml. HCl for the H_2SO_4, results obtained were close to theoretical even in the presence of ammonium salts. Muraca *et al.* (68) found that interfering metals could be removed in the determination of Zn by dithizone by extracting with cupferron and complexing with cyanide and thiosulfate. The limit of detection by this method was 2.5 p.p.m. Zn.

In the determination of total chromium Delaney (20) extracted the colored complex formed with s-diphenyl-carbazide with isopentanol and measured the optical density at 543 mμ. The use of NaCl accelerates the extraction.

Arsenic is another of the elements occurring in some natural waters for which analytical methods have not always been adequate. Berkhout and Jongen (6) after liberation of the As as AsH_3 absorbed it on cotton impregnated with $Pb(OAc)_2$. It is then eluted with NaOH and aqueous Br_2 solution. The As was then converted to the arsenomolybdate, the latter compound was reduced to molybdenum blue, and the optical density measured at 720 mμ. Kobrova (52) carried out the determination of arsenic amperometrically (in concentrations) using short-circuited electrodes without applied voltage. The titration was made in 1 to 2N HCl solution containing KBr using a rotating platinum electrode.

Miller and Brandt (67) found that an extraction adaptation of the colorimetric determination of cobalt with 2,2'2''-terpyridine increased the sensitivity of the method two-fold and eliminated some of the disadvantages due to instability of the color-complex. The color was not affected in the pH range 2 to 10. Beer's law was found to be valid with a Co concentration between 0.5 and 25 p.p.m. The absence of oxidizing agents and cyanides is necessary. Interference by the common metal ions except Fe and Cu ($>$ 100 p.p.m.) and Ni ($>$ 30 p.p.m.) is not serious.

Boron is another of the trace elements whose determination is sometimes necessary in industrial wastes and natural waters. Cypres and Leherte (19) found that they could determine between 0.05 and 50 p.p.m. by the use of carmine reagent. The optical density of the color-complex is measured at 610 mμ. in an $HCl - H_2SO_4$ solution. Preliminary separation of the B as $(MeO)_3BO_3$ is claimed to be unnecessary.

Forster (27) devised a method for quantitatively separating microgram quantities of lithium from sodium and potassium. The lithium was precipitated as the lithium potassium ferricyanide hexamethylene tetramine complex from a water-acetone solution. The yellow complex can be redissolved in water and determined spectrophotometrically.

Halogen Compounds

In the disinfection of water supplies, as well as in the chlorination of sewage and industrial wastes, the determination and differentiation of free and combined chlorine as yet poses a problem. Rich *et al.* (78) correlated five methods in a study of the chlorine demand of sewage. These methods included:

1. Neutral starch-iodide titration.
2. Acid starch-iodide titration.
3. Acid *o*-tolidine determination.
4. Acid amperometric method.
5. Neutral amperometric method.

The authors claim that only the last method has never been reported as subject to interference due to the compounds present in sewage. Based on this, they made a study of the other four methods as compared to this one

on 25 samples of settled sewage. Only the second method gave a coefficient of correlation with the last of less than 0.93. The equations (within 90 per cent confidence limits) also were formulated for the chlorine demands of the first four methods based on the last. The derived equations are as follows, assuming that the chlorine demand, X, is based on that determined by the last method as denoted by Y:

1. $Y = 0.60X + 1.83$
2. $Y = 0.44X + 2.82$
3. $Y = 0.73X + 0.36$
4. $Y = 0.65X + 0.75$

A method for the differentiation of free chlorine and the various chloramine compounds has been proposed as a "Standard Method" in England by Palin (74). This procedure is based on a volumetric technique, using a buffer solution, neutral *o*-tolidine and a solution of $FeSO_4(NH_4)_2SO_4$. Clark (15) used a platinum alloy-copper cell with coaxial electrodes, together with a recording microammeter, for the continuous recording of free residual Cl_2 in conjunction with the amperometric determination of this element. Litvinenko and Rozovskii (57) found that the methyl-orange method was specific for free chlorine, but would not differentiate between Cl_2 and the chloramines. They claim a sensitivity for the method of 0.02 p.p.m. Szypowski (93) used both methyl orange or methyl red in the determination of free and combined chlorine in water samples.

Chlorine dioxide has also been extensively used in water and industrial waste treatment, although the methods for its determination have not been as widely investigated as have those of chlorine. Hodgden and Ingols (39) studied the determination of ClO_2 in water and found that it would produce a colored complex with tyrosine which showed a maximum transmittance at 490 mμ.

Confusion still exists over the merits of the argentometric and mercuric nitrate methods for the determination of Cl^- ion in water and sewage. Ikeda and Komooka (44) eliminated the effects of high $So_4^=$ concentration by the addition of an equal volume of ethyl alcohol. They also recommended the addition of $CdCO_3$ in case H_2S was present. A number of papers (97) (38) (95) (61) have been published on the mercuric nitrate method for the determination of chlorides in water and sewage. Gad and Manthey (32) made a detailed study of the mercurometric determination of the chloride ion and found that under their experimental conditions, Zn, Pb, Al, Ni and Cr^{+3} up to 100 p.p.m. did not interfere. Neither Cu up to 50 p.p.m. nor Cr^{+6} up to 10 p.p.m. was harmful. Iron concentration interference above 5 p.p.m. could be avoided by the addition of two drops of a 5 per cent pyrophosphate solution. The color complex formed at the end of the titration is soluble in ether so if a colored solution is being titrated, a two-phase titration can be made. Badeeva *et al.* (2) in determination of the chloride ion by the mercurometric method recommended the use of 2-nitroso-1-naphthol as an indicator instead of diphenyl carbazone. With the use of the former an intensive red color is formed which is claimed to be due to the formation of 2-nitroso-1-naphthalate of Hg.

The determination of fluorine in water and sewage continues to be the subject of numerous research studies. Beveridge *et al.* (7) and McNulty and Hunter (63) investigated the determination of fluorine using the Al-hematoxylin reagent. A lower limit of 0.1 p.p.m. could be determined without previous distillation of the fluorine. They also concluded that the reaction between F and the Al-hematoxylin complex was not between the F and hematoxylin, but rather between the F and the hematin which is produced

in the oxidation of hematoxylin, and that aluminum hydroxyfluoride is finally formed. Brunisholz and Michod (10) modified the Willard and Winter method (*Chem. Abs.*, **27**, 681; 1933) of distillation of the fluoride ion in which they replace $HClO_4$ with H_3PO_4. They used a small bubble column to prevent the carry-over of any H_3PO_4. They claim that Al and Fe do not interfere and were able to obtain accuracies of ± 0.5 per cent in the determinations. Fuwa (30) used another approach to the distillation of the fluoride ion. The sample was first evaporated to a volume of about 40 ml., keeping it alkaline during evaporation, then concentrated H_2SO_4 (containing 5 per cent of Ag_2SO_4) was added and the distillation carried out under reduced pressure at 145°–150°, the volume being kept constant by the addition of distilled water. In the final colorimetric determination, both the Zr-alizarin and the Al-hematoxylin methods were used. Megregian (64) devised a simple and rapid method for direct determination of F in water or from fluoride distillates. By using certain modifications (including a different Zr lake) readings can be made within 5 min. with an accuracy of 0.02 p.p.m. in the F range of 0.00 to 1.40 p.p.m. A procedure is presented for the elimination of $SO_4^=$ interference. Shaw (83) also presented a procedure for the determination of F in which he substituted the oxychloride for the nitrate (as used in "Standard Methods"). For colored or turbid waters 0.5 g. of carbon were used to clarify a 200-ml. sample. Francis (28) pointed out that the color intensities obtained with the Zr-alizarin reagent varied with the source of supply of these reagents, but by proper adjustment of the strength of the reagent reproducible results (± 0.1 p.p.m. F) could be obtained with permanent glass color standards. Knowlton (51) was able to continuously record the concentration of F being fed to a city water supply. Conductivity measurements are made and recorded by using two cells installed in a water line at a certain distance apart.

Spitzy *et al.* (88) determined 4 μg. of iodine in the presence of 10^4 times as much iodide by a four-stage extraction with CCl_4. The iodine in the extract is reextracted with KOH and determined volumetrically.

Sulfur Compounds

Colombo and Federici (18) made use of countercurrent scrubbing by H_2S-free CO_2 in determination of H_2S in natural waters. The two gases are absorbed in KOH and the H_2S determined iodimetrically. In two samples of natural water, they found 1.52×10^{-6} and 3.69×10^{-6} g. per l. of H_2S. Murthy (69) differentiated between sulfide, sulfite and thiosulfate by means of three separate titrations with chloramine-T. In the first titration $SO_3^=$ is determined. Sulfide is then precipitated with $Cd(OH)_2$ and determined in the precipitate. Sulfite and thiosulfate are determined in the filtrate from the $S^=$ precipitation. From the values obtained in the three titrations, the amounts of $SO_3^=$, $S^=$ and $S_2O_3^=$ can be calculated.

Sijderius (85) in his method for the volumetric determination of $SO_4^=$ precipitated the sulfate with a known excess of standard $BaCl_2$ solution. The excess $BaCl_2$ was then titrated with the disodium salt of ethylenediametetraacetic acid. The presence of Ca and Mg ions interfere and these must first be removed by ion exchange.

Phosphorus Compounds

Levine *et al.* (55) determined phosphorus in waters containing As, Si and Ge. They first precipitated the Al, which carried down the $PO_4^=$ also present. The precipitate was then treated successively with HF, HBr, HCl and H_2SO_4 to volatilize any of the coprecipitated As, Si and Ge. The $PO_4^=$ was then determined by the mo-

lybdenum-blue reaction. They found that the P_2O_5 content in the Gulf of Mexico water varied from 1.8 to 5.9 $\times$ 10^{-6} per cent. Di Bacco (22) also made use of the molybdenum-blue reaction in the determination of phosphorus and arsenic. In this determination the yellow molybdate color was reduced with hydroquinone and Na_2SO_3. They found that hypophosphites do not give the color reaction directly but that an ashing procedure was first necessary.

Cyanogen Compounds

The presence of cyanogen compounds in polluted streams presents a toxicity problem which greatly affects the self-purification of such streams. It is also true that such compounds can increase the cost of sewage treatment where chlorination is used. Myerson and Skupeko (70) made a study at the Detroit sewage treatment plant on the effects of cyanides on the chlorine requirement and found that such compounds were responsible for approximately 15 per cent of the chlorine requirement. They determined experimentally that the presence of thiocyanate was caused by the reduction of CN^- by sewage bacteria. Preservation of cyanide samples posed a major problem. This was solved by addition of 200 p.p.m. of Ni to the sample. "Available cyanides" are defined as those capable of ready halogenation and include simple cyanides, some of the complexes, and thiocyanates. Methods are given for the analytical determination of total cyanides and for the separation and determination of ferro- and ferricyanides, as well as for thiocyanate. Krawczyk (53) reviewed briefly the various methods for determination of cyanides in sewage and suggests modifications for detection and measurement of low cyanide concentrations. These modifications are not applicable to cyanide complexes. Ludzack *et al.* (60) made a detailed study of the various factors involved in the determination of cyanide. Unless it has been found with a given type of sample that acid-distillation can be dispensed with, it should be used with all cyanide samples. The Serfass method of reflux using $MgCl_2$ and $HgCl_2$ gave uniform high recovery of cyanide from both simple and complex cyanides, providing the period of reflux was long enough. Periods longer than 1 hr. are necessary with complex cyanides of Fe, Cu, and Co. If simple cyanides are present, distillation from tartaric acid gave good results. In those cases where steam volatile compounds are present, solvent extraction was necessary before the determination was made, the loss of cyanide by such extraction being negligible. The pyridine-pyrazolone colorimetric method was found to be preferable for cyanide concentrations below 1 p.p.m. and the Liebig titration method for higher concentrations.

Rare Earths

The number of papers being published each year on the determination of the radioactive elements is steadily increasing. Stewart and Bentley (90) determined uranium in salt water by extracting the acidified sample with 0.7 to 0.8M dibutylphosphoric acid with subsequent counting of the U^{238}. They found that the average value for Pacific Ocean water was 2.49 $\pm$ 0.09 γ per liter, and for Great Salt Lake water the values ranged from 4.79 to 5.31 γ per liter. Hahofer and Hecht (36) in their study of the U content of deep-sea sediments fused the sample with Na_2CO_3 and then dissolved the melt with HNO_3 rather than HCl. The $UO_2(NO_3)_2$ was extracted with ether and the U determined by the fluorescence produced with the NaF bead. Rao and Rao (76) found that thorium could be separated from uranium even when the latter element was present in concentrations as much as 70 times that of the former. This

separation was effected by a double precipitation with sebacic acid.

Miscellaneous

In the use of ion exchange methods in water analysis Honda and Tadano (40) studied not only the determination of $SO_4^=$ by such resins but also the recording of the high-frequency conductivity of an ion-exchange resin column. Colmon (17) presented a review of ion-exchangers as analytical tools. Among the topics discussed are: (a) determination of trace quantities of the elements, (b) removal of interfacing ions, (c) chromatographic separation, and (d) concentration of the element under study. A number of specific determinations that can be made by ion-exchange methods are discussed.

Scragg *et al.* (82) designed an instrument for measuring the turbidity of river waters up to a depth of 100 ft. This instrument consists of a lamp and 20-element barrier layer cell contained in cylinders with windows. A second photocell compensates automatically for fluctuations in the light intensity of the lamp. Readings from 0.01 to 100 per cent transmission are made at the water surface by means of a vacuum tube voltmeter connected by cables to the submerged photocells. Roggenkamp (79) redesigned the membrane-filter apparatus for determination of suspended matter in water, which might be especially useful in determining flocculated Fe and Mn compounds in water samples. Wilkenfeld (99) made use of a deep-well pump with the cylinder just above water level for the continuous sampling of sewer flow. All piping was of 310 stainless steel. Approximately 5 g.p.m. was pumped, with a proportional amount being discharged to the sample container. The apparatus is so designed that its operation may be made intermittent with timer control. Rohde (80) used a unique method of sampling the water of the Emscher river to detect any toxic wastes prior to its discharge into the Rhine.

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SEWAGE

Physical and Chemical Methods

Abbas and Raef (1) investigated the effect of temperature on sedimentation of sewage solids at the Gabal-al-Asfar Experimental Station, Egypt, over a period 1951–3. The removal efficiency of a 6-hr. detention period for a comparable range of suspended solids concentrations in raw sewage increased for the higher of two temperature ranges (19° to 25° and 25° to 31° C.) The solids removed per unit time for both temperature ranges decreases as the sedimentation period progresses. Most of the suspended solids were removed during the first hour of settling at temperatures below 25° C., but above 25° C. a relatively greater part of the solids was removed during the second hour. For temperatures above 25° C. and with suspended solids concentration greater than 450 p.p.m. in the raw sewage, a detention period over 3 hr. demonstrated a decrease in solids removed due to turbulence by evolution of gas formed from the putrefaction of the settled sludge. The percentage of suspended matter remaining unsettled varied as a function of the detention period depending on the strength and temperature of the influent.

Kalinske (114) reviews the applicability and limitations of gravity settling and flotation processes in the removal of suspended matter from liquid wastes. He states in general that the flotation process permits the use of smaller basins but yields a thicker sludge and a lower quality effluent with higher power cost than the gravity settling process. He emphasizes the need for laboratory, and in some cases, pilot plant studies, for selecting the most feasible process for a particular waste.

Comings, Pruiss and DeBord (52) describe a model thickener to study the limiting conditions of sedimentation and thickening of inorganic slurries. The effect of the depth of compression zone, the time of detention in this zone, and rake action on the underflow concentration was also investigated.

Wollner, Kumin and Kahn (206) report the development of a practical method for the clarification and re-use of soapy laundry water. Alum was used as the coagulant, with soda ash or caustic soda as the neutralizing

agent. Diffused air bubbles cause the flotation of the sludge, which is continuously removed from the surface of the flotation chamber. The clarified effluent is removed from the bottom of the chamber and pumped to a storage tank for re-use in laundering. About 87 per cent of the laundry water requirements can be recovered in this fashion.

Symons (191) describes a tubular conveyor for handling grit. The conveyor consists of a tube through which an endless chain moves. Between every link in the chain is a close-fitting disc which transports the grit. The material can be moved around a 90° corner.

Peformance tests on a microstrainer for screening trickling filter effluent were reported by Keefer (117). The experimental unit is cylindrical, with stainless steel fabric containing 75,000 apertures per square inch. Suspended solids removed from filter effluent averaged 56.1 per cent when the screen operated at 30 sec. per rev. and 58.9 per cent at a speed of 50 sec. per rev. The B.O.D. removals averaged 38.4 per cent. The performance was reported as being comparable to that of properly operated humus (final) tanks.

At Salford, England, Stones (182) conducted experiments with chemical precipitation of sewage containing industrial wastes and compared the results with sewage from purely domestic origin. Alum, with and without lime additions, was employed. Optimum precipitation occurred at pH 5.0. Precipitation with aluminum sulfate under acid conditions led to the conclusion that the active precipitating agent is aluminum hydroxide formed as the result of hydrolysis, and not aluminum ions. Aluminum sulfate is hydrolyzed at normal pH values so that the addition of lime to insure the formation of aluminum hydroxide is not only unnecessary but may be a definite disadvantage. The same author (184) also reported the results of experiments with acid precipitation of sewage containing industrial waste. Acid precipitation is a function of the pH value and is independent of the nature of acid employed. Optimum precipitation occurred at pH 3.0, which requires subsequent neutralization prior to biological treatment. Acid does not disperse any of the settleable matter present.

Improvement of domestic sewage sedimentation using aluminoferric coagulant was reported by Harwood (91).

Lea, Rohlich and Katz (130) report that 96 to 99 per cent of the soluble phosphates can be removed from sewage plant effluent by coagulation-adsorption with floc of filter alum or iron salts, the former being the most effective. Recovery of alum for re-use in phosphate removal gives an 80 per cent reduction in the cost of the chemicals employed. With 200 p.p.m. of recovered alum, 77 to 89 per cent of soluble phosphate can be removed. Approximately 85 per cent of the biologically oxidizable organic compounds and 68 per cent of the organic nitrogen compounds are also removed.

Biological Filters

Gerber (78) has combined some of the variables affecting trickling filter efficiencies into a dimensionless product and correlated it with the B.O.D. removed: B.O.D. applied ratio. The dimensionless product is H/DK_1 where H is the hydraulic dosing rate in feet per day, D is the filter depth in feet, and K_1 is the B.O.D. rate constant in 1/day. The efficiency ratio is the B.O.D. remaining at depth D divided by the applied B.O.D. Data are presented for filter efficiencies of 60 to 90 per cent, loading rates of 3.68 to 16.39 m.g.a.d., filter depths of 2 to 7.25 ft., B.O.D. loads of 375 to 8,175 lb. per acre-foot, and temperatures of 69° to 75° F. The data were taken from one plant alone where the filters operated without recirculation and the

sewage rate constant was assumed to be 0.2 per day. K_1 values were adjusted to 20° C. For dimensionless factors less than about 50 a fair relationship is shown. Another article (15) presents graphical methods for predicting the efficiency of B.O.D. removal by biological filters. The expected reduction may be determined if the filter depth, area and surface loading, and the B.O.D. and temperature of the settled sewage are known.

Use of a high-rate roughing filter to increase the capacity of an activated sludge plant has proven to be most satisfactory (10). The filter is 53 ft. in diameter, 6 ft. deep, and utilizes 2- to 4-in. slag as medium. The designed dosing rate is about 30 m.g.a.d., which will load the filter at about 2 lb. of B.O.D. per cubic yard per day. During 6 months of operation the filter removed 59 per cent of the applied B.O.D. load based on hourly sample composites over an 8-hr. period during the daytime.

Imhoff (106) reviews historical highlights in the development of trickling and intermittent sand filters. Starting with the sewage farms in England 100 years ago he traced the development of intermittent sand filters from this process to the investigations at the Lawrence Experiment Station. The contact bed method followed, but it was soon realized that such beds have the great defect of retaining the sludge resulting from biological purification. The trickling filter method shortly became the process of choice and it has seen almost continuous development and improvement to date.

A comprehensive historical review of the development of biological filtration is given by Stanbridge (181).

The sodium sulfate soundness test is not applicable to trickling filter media in semitropical areas according to Furman (75). He also concludes that 4-ft. filters are of economic advantage in such areas because the applied B.O.D. is removed at a rate of 60 per cent per 2 ft. of bed depth as opposed to 50 per cent in the temperate zones. Standard-rate filters may be loaded in excess of 4 m.g.a.d. with but slight decrease in efficiency. At 10 to 12.5 m.g.a.d. and organic loadings in excess of 2,500 lb. per acre-foot per day, ponding trouble was experienced whenever the air temperature fell below 45° F. The results of continuing pilot plant studies on intermittent sand filters have also been reported by Furman (75) for semitropic areas. It was found that sand ranging from 0.25 to 0.35 mm. may be loaded at 0.175 m.g.a.d. with settled sewage; 0.45-mm. sand will effectively treat 0.20 m.g.a.d.; and 1.04-mm. sand may be loaded at 0.40 m.g.a.d., all when dosed twice per day. Some increase in B.O.D. removal efficiencies was noted for sands of less than 0.35-mm. size when the number of loadings per day was increased above two. Tests on B.O.D. removal at various bed depths revealed that efficiencies are not appreciably increased by increasing sand depths beyond 18 in. for sands smaller than 0.45 mm. Gloyna and Smith (80) report that tests on 18-in. dia. experimental filters show shallow separated filters to be much more efficient than conventional filters of the same total depth. The test units consisted of six 1-ft. sections, with a 2-in. separation between each section, and a 6-ft. well-aerated filter. The medium was 2- to 4-in. limestone. The settled domestic sewage was applied to both units at 4.5 m.g.a.d. and had a strength of 140 and 152 p.p.m. B.O.D. for the separated and conventional filters, respectively. The average B.O.D. removal by the sectional filter plus settling was about 90 per cent, as opposed to 75 per cent for the conventional filters.

Bernhart (30) described a trickling filter consisting of many individual cells stacked in tiers about 7 ft. high. The cell units are of precast con-

crete, shaped like channel iron placed horizontally with flanges up. The space between flanges is filled with coarse filter material. The channel web is perforated to allow the passage of the sewage from top to the lowest cell. The filter requires no mechanical equipment or piping, permits heavy dosing and is suitable for small installations (50 to 1500 people) at minimum cost of construction and operation.

Gaillard (76) has presented operational data on five of Johannesburg's six filter plants and has compared the results in terms of an arbitrary "load unit." A unit is defined as the product of dosage (gal. per cu. yd. per day) and strength (O.A., or oxygen absorbed from permanganate in 4 hr.) The filters are 6 and 12 ft. deep containing media of ¾-, 1-, 2½, and 3-in. stone. Twenty-four hourly samples were taken at 8-day intervals for a one-year period and the results at each plant averaged. The load units varied from 6,200 to 28,200. Some of the filters were dosed with well-nitrated effluents, either by recirculation or by diverting effluents from other treatment units. This practice has been most beneficial. For example, the largest volume of settled sewage (O.A. = 100 p.p.m.) that one plant could treat to full purification prior to recirculation was 80 g.p.d. per cubic yard (that is, 8,000 load units). When nitrified effluent was recirculated at 1:1 ratio, the rate of flow was increased to 120 g.p.d. per cubic yard (12,000 load units) without reducing the effluent quality. The general aim at all plants has been to produce effluents with an O.A. value lower than 20 p.p.m., and this has corresponded with a nitrate production of at least 10 p.p.m.

In an attempt to define the effects of treating gas works liquor in admixture with sewage in trickling filters, Blackburn *et al.* (32) have made pilot and plant-scale investigations of various constituents of gas liquor on the biological oxidation of settled sewage. Tests with spent gas liquor were made in two filters each 39 ft. in diameter and 6 ft. deep containing ½-in. rock. Addition of the liquor in a 0.5 per cent concentration by volume caused a significant deterioration in the effluent quality. Tests with the crude liquor fractions were made on filters 1 ft. in diameter and 6 ft. deep. The greatest deterioration in effluent quality was caused by addition of two fractions, one containing thiocyanate, ammonia, and certain organic substances, and the other containing carboxylic and "humic" acids. The fractions containing polyhydric phenols were more deleterious as measured by the O.A. test than those containing monohydric phenols, but the effect of all fractions on the effluent B.O.D. was similar.

Clifford (51) reported additional experimental work on the effect of gas liquor on the treatment of sewage by trickling filters. The control filter received 0.43 per cent by volume of pretreated (by concentration and dephenolation) gas liquor. To the second filter an additional dose of the same gas liquor was superimposed so that the total volume of gas liquor applied amounted to 0.69 per cent. Sewage was applied to both filters at the rate of 100 g.p.d. (Imp.) per cubic yard. The added load affected the effluent adversely. By recirculation of effluent to the filter, the volume of gas liquor applied could be doubled.

Goldthorpe and Taylor (81) reported that the pretreatment of gas liquor by steaming resulted in satisfactory treatment of the sewage by trickling filters in much higher concentration of the gas liquor.

Tucker (195) has recorded the starting-up of four 100-ft. diameter filters containing 2½-in. media. The settled sewage as applied contains a high percentage of industrial wastes and is in a septic condition. The aver-

age 4-hr. O.A. figure is about 105 p.p.m. Two filters were started at 200 g.p.d. per cubic yard and the loading was decreased to 100 g.p.d. per cubic yard after 4 weeks because a 50 per cent reduction of 4-hr. O.A. was experienced. An additional 13 weeks of dosing at the reduced rate produced a well-nitrated effluent which was about 70 per cent oxidized by the O.A. test. The other two filters were loaded at 50 g.p.d. per cubic yard, which value was increased to 80 after 12 weeks. After the 16th week these filters were producing an effluent of approximately the same quality as that of the other filters.

Investigations have been made by Meltzer (144) on the effect of peripheral 6-in. ventilation openings situated at the 6-ft. level of 12-ft. trickling filters and extending radially to the center. Two pairs of filters producing effluent of similar quality were fed a mixture of settled sewage and settled primary filter effluent. The vent on one filter of each pair was closed, but no significant differences in the quality of effluent were observed. Of the two pairs of filters used, the pair containing the smaller media produced an effluent containing significantly more nitrate.

A description of the design of a new trickling filter plant has been given by Bartlett (25). The design capacity is 2.1 m.g.d. from 40,000 persons; the effluent standard was established at not more than 20 p.p.m. B.O.D. nor 10 p.p.m. suspended solids. The first stage of construction is to include four of the eight 104-ft. diameter filters of 6-ft. depth which will contain 2½-in. media. Filters are to be operated with recirculation and were designed at 140 g.p.d. (Imp.) per cubic yard of settled sewage plus 280 g.p.d. (Imp.) per cubic yard of effluent. Filter floors will be constructed of floor tiles draining to central wells. Vent pipes will be located at 10-ft. intervals on the periphery and sampling pipes will be placed at 1-, 3-, and 5-ft. depths in the media. Ferrell (68) describes problems encountered in an underloaded single-stage biofiltration plant. The plant is designed for an average flow of 0.96 m.g.d. with peak loads of 1.8 m.g.d. At present the detention period in the clarifiers is 3.5 hr., or twice the design period. Consequently, difficulty is experienced in keeping a good growth on the filter media. The most practicable solution was found to be recirculation of the effluent from the secondary clarifier to the inflowing raw sewage. Johnson (112) reports on the design of a standard-rate trickling filter plant to handle a flow of 0.6 m.g.d. from a USPHS narcotic addicts hospital. Shock loads from the hospital and its dairy, laundry, slaughterhouse and cannery necessitated that the existing activated sludge process be replaced by the more rugged filter. The average B.O.D. is 200 p.p.m.; the suspended solids, 225 p.p.m. The filter is 100 ft. in diameter with a 10-ft. depth of stone placed over tile underdrains. At design flow the organic loading is about 0.23 lb. B.O.D. per cubic yard per day.

A unique stone filter combined with a septic tank has been described by Le Bosquet and Ludwig (13). The system is built as a unit below ground, with the septic tank effluent being distributed over the filter by means of concrete troughs. The bed consists of three 10-in. stone layers which are ¾-, 1½-, and 3-in. in size. Both top and underdrains are vented to the atmosphere. No operational data are available, although such filters have been used in the Congo for more than 30 years.

Arthur (20) describes a new 30-m.g.d. biofiltration plant for Beaumont, Tex. The raw sewage is extremely variable (48 to 1,020 p.p.m. B.O.D.; 98 to 1,240 p.p.m. suspended solids on samples from seven points in the collection system). The plant has

two primary and two secondary filters, each 195 ft. in diameter, with clarifiers preceding the primary and following the secondary filters. The filters average 4-ft. depth of stone and are designed for 0.4 lb. B.O.D. per cubic yard per day applied load. A 1:1 recirculation ratio is provided from the primary filter to the primary clarifier and the secondary clarifier effluent is recirculated to the secondary filter in the same ratio.

Zack (212) has presented in very condensed form the design criteria of trickling filters as normally used for sewage and industrial waste treatment plants. The items covered include depths, recirculation ratios, surface and volume loadings, and expected efficiencies. Another report (14) lists the important items to be considered in specifying trickling filter media. The following criteria should be met: (a) The stone should be retained on a screen having 2-in. square openings and should pass through a screen having 3½-in. square openings; (b) it should be free from dust, clay, sand or fine material; (c) it should be resistant to spalling or flaking under the sodium sulfate soundness test; and (d) it should be placed in the filter in a manner that will prevent breaking the underdrain system or the stone. Ponding and inefficient operation will result if these standards are not met.

Studies of biological filtration of sewage (202) were continued at Minworth, England, for the purpose of learning the effect of periodicity of dosing on the treatment of settled sewage by alternating double filtration. Four 120-ft. diameter filters equipped with rotary 4-arm distributors were used, and the results from treating settled sewage at a rate of about 150 g.p.d. (Imp.) per cubic yard of medium are reported. The distribution of liquid in a trickling filter was also investigated, together with some factors affecting the growth of microorganisms.

In a description of Orlando's new two-stage series-parallel biofiltration plant, Swift (190) states the construction cost was about $12 per capita based on 80,000 design population. The design flows for a raw sewage averaging 102 p.p.m. B.O.D. are 8 m.g.d. average and 16 m.g.d. maximum. Two primary and two secondary filters are all 120 ft. in diameter and 5 ft. deep, with 1½- to 4-in. media. The sewage flows from the primary clarifier to the primary filter, from which it is recirculated to the clarifier at a ratio of 0.84. Part of the clarifier effluent is diverted to the secondary filter, whence it flows to the secondary clarifier and is recirculated to the secondary filter at a ratio of 1.46. All sludge from the secondary clarifier is returned to the primary clarifier, where the B.O.D. removal averaged 76 per cent and the suspended solids removal 70 per cent for the year. The high percentages are attributed in part to the effect of the humus recirculated from the primary filter and the secondary clarifier, which settles rapidly and carries with it the organic matter in the raw sewage.

Hesseltine (96) has reported the results of a year's microbiological study on trickling filter fungi. The filters receive miscellaneous chemical wastes and large amounts of antibiotic production wastes. Three species of fungi were found at all times and were considered to be the only species regularly inhabiting the filters, with other observed molds being considered chance contaminants. The fungi were *Fusarium episphaeria*, *Oospora lactis*, and a new species *Subbaromyces splendens*. Popp and Bahr (160) report that wastes from an industry manufacturing hexachlorohexane, when mixed with municipal sewage, reduce the efficiency of trickling filters by reduction of organisms such as *Colpidium*, *Vorticella*, nematodes, *Psychoda* larvae and blue-green algae. Dilution tests showed *Colpidium*, *Oscillatoria*,

and *Daphnia* to be the most sensitive of the organisms tested.

Activated Sludge

A symposium on the activated sludge process in Great Britain (132) (133) (38) (64) (200) (110) (65) (138) (194) traced the activated sludge process and its various modifications from their beginning to the present. The original paper of Ardern and Lockett was reprinted for the occasion.

Much has been written recently to explain and develop the theoretical principles of aeration. Haney (88) has critically reviewed the available information. Pasveer (154) showed that the rate of biochemical oxidation increases with the decrease in the size of floc. Since the size is related inversely to the turbulence, he concludes that increased turbulence in the mixed liquor may be an important factor in transferring oxygen to the floc and in increasing the rate of biochemical oxidation. Pasveer (155) defines oxygenation capacity as the rate of oxygenation (at standard conditions of distilled water at 10° C and 760 mm. for an oxygen content of 0 p.p.m.) expressed in grams per hour per cubic meter. He believes that the purification capacity of an activated sludge plant is governed primarily by the oxygenation capacity and that it is possible, by increasing the oxygenation capacity and the degree of turbulence, to obtain complete purification of much larger amounts of sewage per unit volume of aeration tank than heretofore. According to King (122), the high oxygenation rates of 400 g. per hr. per cu. m. observed by Pasveer (153) were obtained under impractical conditions using very shallow tanks. For aeration tanks 15 ft. deep, the capacity of brush aeration is such as to satisfy only moderate oxygen requirements. Tests indicate that rates of oxygenation, by means of diffused air, up to several times present day requirements can be obtained in any depth tank and at lower power per unit of oxygen absorption than reported by Pasveer for brush aeration.

Data have been presented by Ippen and Carver (109) to show the effect of some basic factors on oxygen transfer in aeration systems. In a discussion, Dobbins (62) pointed out that the transfer of oxygen across the surface area of a tank is an important factor for diffused air aeration and should be computed separately in studies of this kind. The effect of various surface active agents on aeration rates in clean water was studied by Holroyd and Parker (99) using various types of apparatus. They found that the rate of oxygen transfer through an aeration surface is greatly influenced by the character of that surface. Three reagents, turkey red oil, an anionic detergent and a nonionic detergent, in amounts up to 100 p.p.m. in clean water, have shown effects similar to those observed by others when sterilized sewage was aerated.

Wuhrman (208) has shown in pilot plant studies that with short aeration periods (65 to 143 min.), hydraulic loadings of 164 g.p.d. per cu. ft., and B.O.D. loadings up to 191.3 lb. per 1,000 cu. ft. of aerator volume, B.O.D. reductions of at least 80 per cent were obtained with settled domestic sewage. Using the respiration rates of the sludge and the oxygenation capacity of the plant, he suggested a method for estimating the sludge concentration which can be maintained aerobically. Wuhrman (209) also described river biocoenosis in terms of the relative abundance of heterotrophic and autotrophic microorganisms. An effluent satisfactory for discharge into a river must only induce a biocoenosis of autotrophic organisms. No heterotrophic growth should be visible to the naked eye. Channel experiments, using settled sewage and biologically

treated sewage, indicated that biological treatment produced changes in sewage compounds so that, even with equal concentrations of B.O.D. and organic nitrogen and carbon, the environment is more favorable for the development of autotrophs in biological effluent than in sewage.

Smith and Johnson (179) showed that with pure culture of bacteria (*Serratia marcescens*) the per cent yield of cells based on substrate utilized and the live cell count varied directly with aeration efficieney.

Corti (55) studied the amino acids in the hydrochloric acid hydrolyzates of fresh, centrifuged and dried sludge. He isolated seven of them in crystalline form and obtained quantitative data on seven others. Tryptophan was absent. The yield of amino acids amounted to 30 per cent on an ash-free basis. Chromatography analyses by Pillai *et al.* (159) showed that 15 different amino acids were found in the hydrolyzates of raw sludge and activated sludge. All but alanine, proline and tryptophan were found free in raw sewage and only free cystine and proline were missing in activated sludge. The purified effluent was practically free from amino acids.

After reviewing the available information on the effect of temperature on the performance of activated sludge plants, Krause (124) concluded that the data are very conflicting and that more information is needed for plant design. Horasawa (101) attempted to show that there is a relationship between the surface area of activated sludge, loading, protozoan activity and purification of sewage by the activated sludge process. Nelson, Reading and Christensen (151) found that three batch-fed activated sludges, each fed with different flour-sugar mixtures were able to oxidize oxalic acid in feed concentrations up to 2,000 p.p.m., which amounted to 83 lb. per 1,000 cu. ft. of aerator volume per 24 hr. About 2 to 3 weeks were required for acclimation of the sludge. A laboratory-scale unit for continuous feeding activated sludge experiments was described by Hatfield and Strong (92).

Chasick (49) has reported on a new process, activated aeration, which comprises the aeration of settled sewage for about 2.8 hr. in the presence of excess activated sludge taken from an adjacent unit. Air requirements, averaging about 0.2 cu. ft. per gal., were near the minimum required to keep the solids in suspension. The effluent, including that from the thickening tanks, averaged 31 p.p.m. of suspended solids and B.O.D. The combination of activated aeration and activated sludge accomplished a reduction of 86 per cent in the raw sewage suspended solids and 85 per cent in the B.O.D. After final settling, the solids were wasted directly to thickening tanks for disposal.

Unrestricted free-falling conditions for particles of activated sludge prevail up to the fifth to eighth minute of the settling period and after that the particles are affected by consolidation. Since the rate of settlement of the sludge is a prime factor in the control of aeration processes, Finch and Ives (72) suggest that the

$$\text{sludge index} = \frac{\%\text{ sludge settled in 6 min. (volume)}}{\text{gm. suspended solids per 100 ml.}}.$$

An alternate method consists of plotting the percentage of settled sludge by volume against time and determining the tangent of the angle subtended by the free-falling portion of the curve and the vertical. The slope of the curve represented by 1,000 times the tangent of the angle is the

sludge index. The authors also show the importance of careful handling of sludge.

According to Finch (70), Britain's first major sewage scheme constructed since the end of World War II is the London County Council Beckton Extension. This plant, which will treat about 60 m.g.d., will be supplied with diffused air and may be operated as step or tapered aeration. The Enid, Okla. (189), and the Miami Virginia Key (31) sewage treatment plants may also be operated with step aeration.

At the Philadelphia Northeast plant, Hoot (100) reported that both low mixed liquor solids and relatively high solids have been used in the high-rate sludge process with no clear-cut advantage in the use of either. The best removals were obtained with 600 to 800 p.p.m. mixed liquor solids when the raw sewage contained 206 p.p.m. suspended solids and 128 p.p.m. B.O.D. The final effluent contained 13 and 14 p.p.m., respectively. The air requirements were 0.55 cu. ft. per gal. At the other extreme, according to Finch (71), Brown reported that the plant at Colne Valley, England, had been operated with 10,000 p.p.m. suspended solids in the mixed liquor, using 2 cu. ft. of air per gallon of sewage. Kessener (119) has pointed out the advantages of brush aeration. The dimensions and capacities, together with descriptions and some design data for the three Chicago plants, were presented by Anderson (8). Average operating data for these plants were also shown. Lamb (126) has reviewed the use of porous tube diffusers from the standpoint of design and maintenance.

Frothing at activated sludge plants continues to cause trouble. In Los Angeles (174) it has been controlled by water sprays and the intermittent use of anti-foam chemicals. At the Benton Harbor-St. Joseph, Mich., plant (167) froth has been present on the aerators since the start of secondary treatment. Variations in dissolved oxygen concentration, return sludge ratios and aeration solids (1,000 to 3,500 p.p.m.) were of no help in checking froth. Spraying of raw sewage on the surface of the tanks controlled it. At Neersen, Germany, Rohde (165) reported that the froth was broken up by jet discharge of sewage over the tank.

According to Finch (69), Lumb concluded that the efficiency of the activated sludge process is adversely affected by small concentrations of detergents of both anionic (alkyl aryl sulfonates) and nonionic types. The deterioration of treatment efficiency becomes significant when the detergent concentration reaches about 10 p.p.m. in settled sewage and increases sharply above this level.

Disinfection

Allen and Brooks (6) studied factors affecting disinfection by chlorine and concluded that free chlorine is more effective than chloramines because of rapid kill obtained before the chlorine combines to form chloramines. Dickerman, Castraberti, and Fuller (60) found that ozone effectively sterilized water in the presence of a small amount of organic matter, but with increasing concentration organic matter higher dosages and longer contact times were required. Two articles (28)(24) discussed the use of chlorine dioxide, which was found to compare favorably with chlorine except that it cost more. Kruse (125) gives a quick method for the generation of chlorine dioxide.

Russell, Buswell, Fry and Whitney (168) discuss the instrumentation and equipment needed to make a bacteriological study using ultrasound. Two articles (145)(54) discuss the radiation required for disinfection. Hofmann and Enhuber (98) studied disinfection by silver compounds and found a contact time of 3 to 9 hr. is required at a maximum concentration

of 50 μg. per liter. Braune (42) studied disinfection by silver compounds in the form of filter media and concluded that the prior removal of suspended matter is required for efficient disinfection. Riehl, Hartung, and Taylor (164) studied bacterial reductions by lime treatment and concluded that sufficient lime addition to give a 2 to 3 p.p.m. caustic alkalinity and 3-hr. retention time effected a coliform reduction of 83.5 per cent.

Hermanowicz and Dozanska (95) studied disinfection by chlorination and found the oxidation reduction potential increased with increasing bacterial removals. They also developed a first-order equation for bacterial reduction and contact time. Bergsman and Vahlne (29) studied the removal of tubercle bacilli by chlorine and found that raw sewage required 2 p.p.m. and septic tank effluent 15 p.p.m. Jensen (111) found a 10-p.p.m. dose destroyed the tubercle bacilli in activated sludge effluent. He also studied the disinfection of sludge and found that 0.5 per cent lysol and 0.1 to 0.2 per cent formol was effective, but 3.1 per cent copper sulfate was ineffective. Clarke and Kabler (50) found that it took approximately 7 to 46 times as much free chlorine to kill the Coxsackie virus as was required to kill *Escherichia coli*.

Wang and Dunlop (201) studied disinfection of sewage prior to use for irrigation. They concluded that primary treatment and a 0.3-p.p.m. chlorine residual effected the following removals: 99 per cent coliform, 80 per cent *Ascaris* ova, and 54 per cent *End. coli* cysts. Nakata (150) concluded that 4 to 40 p.p.m. of free chlorine were required for mosquito control.

Pearce (156) discusses equipment used for chlorine gas feed and Langworthy (129) gives various methods used to control chlorination. Ingols, Hodgden, and Hildebrand (108) published an interesting article on the taste and odors produced by chlorination of nitrogenous compounds. It is brought out that the threshold odor concentration of some of these compounds is a few parts per billion.

Sludge Digestion

Theory and Mechanism

Investigations to isolate and study various bacteria responsible for the digestion of sewage solids were continued by Buck, Keefer, and Hatch (43) at the Back River sewage treatment works in Baltimore, Md. An organism not previously reported in the literature was isolated from actively digesting sewage. It was found to be a liquefying, facultative, aerobic, non-pathogenic bacillus which grows in chains or singly. The organism is quite motile and the cell contains motile endobodies. Because of these characteristics the authors suggest the name *Bacillus endorhythmos*.

Growth of *B. endorhythmos* occurs over a wide range of pH and temperature values. No gas was produced by the organism on various media tested, but raw sewage solids were liquefied and gasified. On sterilized raw sludge, however, no gas was produced, leading the authors to conclude that the organism acts in synergism with gas-producing bacteria.

Further studies (115) of *B. endorhythmos* showed that maximum gas production occurred when the pH of sludge was maintained at 6.4, but that throughout the pH range from 6.8 to 8.0 gas production by the organism exceeded that of the control, falling below only at pH 8.4. Reduction of volatile solids was greatest at pH 7.6 and 8.0, and least at 6.4. The authors conclude that the organism is highly effective in decomposing sludge over a wide range of pH values.

Maki (137) demonstrated that cellulose fermentation may be the limiting factor in the rate of sewage sludge digestion. Cellulose has been shown to be one of the principal constituents

of sewage solids; and investigations showed cellulolytic bacteria to be present in numbers as high as 1×10^6 per ml. Ten cellulolytic strains were isolated and studied by the author. All strains showed better growth in solid than in liquid media. Agar was found to possess growth-promoting properties for some strains. For some, phyton and tripticose could replace agar, but the others could not grow when no agar was present. H, CO_2, ethanol, and formic, acetic, and lactic acids were identified as fermentation products; glucose was shown to be a product of cellulose digestion. Cellobiose, starch, dextrin, and maltose were fermented by five strains of organisms studied, inulin and esculin by one; none of 17 other carbohydrates, including glucose, were attacked. Concentrations of acetate up to 5,000 p.p.m. had no effect on the rate of cellulose fermentation by a pure culture. The rate of cellulose fermentation by a mixed culture of *Clostridium sp.* and a cellulose decomposer was much greater than by the latter alone.

Various reports concern the fate of several materials during digestion of sludge. Nelson, Reading, and Christenson (151) reported that anaerobic digestion of oxalic acid did not occur in experiments with two-stage digesters. Bloodgood (35) noted that fats and oils will digest if not present in such amounts as to form mats. Hewitt (97), reporting on five British plants treating various mixtures of sludges, noted that a higher proportion of the B.O.D. was contained in sludges from purely domestic sources than in sludges containing trade wastes. He also found that the volume of liquid sludge varied from 0.31 to 0.19 per cent of the sewage flow.

Langford (128) considered sludge digestion from the point of view of making it a process for the controlled production of a fertilizing material. In this case a fourth stage of digestion might be added to the usual three—intense acid production, acid regression, and intensive digestion of more resistant materials. This fourth, or "humification" stage, is a period of decreasing gasification accompanied by an increase in pH. Longer periods of digestion are not suggested by the author, who points out that digestion rates are about 10 per cent per day, yielding 90 per cent digestion in 22 days and 95 per cent digestion in 28 days. Activated sludge is reported to digest at a rate of 5 per cent per day.

Active amylolytic enzymes were found adsorbed to the sludge in septic tanks by Evreinova *et al.* (67). They also found proteases both in the sludge and supernatant liquor.

A number of researchers continued to investigate additives such as bacterial cultures, enzyme systems, and other biological agents for which various claims have been made regarding beneficial effects upon the sludge digestion process. The effect of additives advertised as reducing suspended solids and B.O.D., improving supernatant, raising the pH, and increasing gas production was studied on a laboratory scale by Grune and Sload (87). Both fresh and digested sewage solids were studied under controlled conditions in 1,000-ml. digesters. Uninoculated solids, solids inoculated with from 5,400 to 53,300 p.p.m. of biocatalysts, and solids with added protein were investigated. The principal findings were that (a) the rate of gas production was not significantly altered by the addition of biocatalysts; (b) the volume of gas produced did not increase as a result of biocatalysts over that of similarly prepared mixtures, with or without protein preparations; (c) the total ultimate gas production was not significantly benefited; (d) the gas yield in pounds per cubic feet of volatile solids destroyed was not different than with added protein; (e) the per cent reduction in volatile solids was less in the presence of biocatalysts than in controls without pro-

tein, while a protein equivalent produced more gas than biocatalysts; (f) the beginning of methane production was not hastened by biocatalysts; (g) the rate at which equilibrium was established was not affected by 4,200 to 6,400 p.p.m. biocatalysts added after the initial period of acid digestion at temperatures of 30° and 7° C.; and (h) no increased benefits were observed from the use of 1 per cent biocatalyst during 30° and 7° C. studies. The authors conclude that it is unlikely that a treatment plant digester will be benefited to a greater degree than the laboratory digesters studied.

Results of tests of biocatalytic agents by sewage plant operators in California were contained in a committee report by McKee *et al.* (142). No effect of biocatalysts on gas production, pH, alkalinity, and/or volatile acids in digestion was found. One operator reported using an additive in starting gas production. Two others, however, ran controlled tests and found no benefits in starting gas production. The possibility is suggested that enzymes of some biocatalytic agents might reduce scum blankets, but no evidence is offered. The committee makes a number of pertinent recommendations to both users and manufacturers of biocatalysts in the interests of further investigation. Sampson (169) reported no benefit from enzymes in overcoming difficulties in digester operation.

The normal affect of temperature on sludge digestion was recalled by Bloodgood (35), who pointed out that decomposition of solids practically stops below 50° F., shows a great difference in rates at temperatures between 70° and 80° F., and is most rapid in the 85° to 95° F. range. Significant plant-scale experiments on the effect of higher temperatures on digestion of sludge from the modified aeration activated sludge plant (Hyperion) at Los Angeles were reported by Garber (77). Temperatures from 85° to 120° F. were investigated under a wide variety of operating conditions including 1-, 2-, and 3-stage digestion. No advantage was found in digesting at 100° instead of at 85° F. However, 120° F. produced a profound effect on the characteristics of sludge. The 120° culture was quite stable and resistant to upset, even when a temperature drop of 9° occurred within 48 hr. At any temperature a period was required for cultures to become established, but once established, cultures at one temperature produced about the same results as at another, the same degree of digestion being accomplished for any given rate of loading. Operational procedures within any temperature range had no effect as long as seeding and mixing were suitable, and under similar conditions of operation 3-stage and 2-stage digestion had no advantage over a single stage. The principal effect of 120° F. digestion was a greatly increased filterability of the sludge. The sludge from 120° digestion was found to be low in nitrogen, but the gas produced was high in methane. Garber concludes that the advantages of 120° F. digestion far outweigh the disadvantages.

An advantage of thermophilic digestion is pointed out by Muller (149) who found that the process completely destroys *Ascaris* eggs. Mesophilic digestion, on the other hand, is reported by this investigator to require a detention period of six months plus six months of drying. Heating of sludge to 55° C. for 2 hr. would obviate the need for long digestion and drying periods.

Anaerobic digestion of night soil was discussed by Horasawa (102). He found that two stages occur in gas production from this material. The first is a high-rate period lasting from 2 to 25 days and yielding up to 30 per cent of the total gas. The second stage is longer and starts slowly, producing a sigmoid curve similar to that

of sludge digestion. Digestion and gas production were found to be favored by seeding and by the addition of carbohydrates.

New Developments

A number of new developments aimed at increasing the economy of sludge digestion or at reducing operational difficulties were reported. Morgan (146) described laboratory and pilot plant studies leading to the conclusion that it is possible to complete anaerobic digestion of sewage solids in approximately one-third of the time normally considered necessary. Digester loadings of 0.345 lb. volatile solids per cubic foot per day and a tank displacement period of 7.2 days were successful. The process requires the recirculation of diffused gas throughout the digester to bring seed sludge, raw sludge, and gas into intimate contact. To accomplish this, centrally located gas diffusers were placed near the bottom of the tank. A temperature of 95° F. was maintained. The result was a well-stabilized sludge, with normal gas production. Mechanical separation of sludge and supernatant was accomplished in a separate tank after the 7.2-day digestion period. Sludge drying qualities of the final sludge were found to be equal to those from long-time digestion. A design loading of 0.2 lb. per cu. ft. per day is recommended.

The process described by Morgan was tried by Blodgett (33) on one operating digester at Columbus. After three weeks of progressively increasing digester loading, the digester was operated successfully for four months at a loading of 0.286 lb. per cu. ft. per day, and at a tank displacement time of 14.4 days. These values represent 275 and 55 per cent, respectively, of normal loading and displacement rates.

Fuhrman (74) reported the development of a new method for combatting scum. The procedure involves injecting sludge gas below the scum layer at a rate that brings about disintegration of the scum. In a new tank, scum formation is prevented, whereas in an old tank the effect is to disperse any existing scum cap and prevent the formation of another. In using the process at a treatment plant in Washington, D. C., power requirements were found to be low, and the results immediate and spectacular. Application of the method was found to allow an increase in tank loading to values of at least 0.12 to 0.15 lb. volatile solids per cubic foot per day in a heated tank. Langdon (127) reported successful application of the method in Toronto to disperse scum 15 ft. thick and containing 20 per cent solids, of which 60 per cent were nondigestible.

Pilot plant studies of high-rate sludge digestion were conducted at Iowa City. Morgan (147) showed successful results with loading of 0.277 lb. volatile solids per cubic foot per day over a period of ten months, with one-month averages as high as 0.345 lb. It was concluded that loadings of 0.2 lb. volatile solids per cubic foot per day are feasible, and even higher values might be used in multiple digester installations. Laboratory studies by the same investigator showed that the maximum rate of conversion of organic matter to gas is reached in 3 to 5 hr. after feeding raw sludge. Digestion was sometimes completed in 55 hr., hence theoretical digestion periods of less than three days, and practical periods of seven to ten days are deemed possible.

Sludge thickening ahead of the digester as a means of increasing its effective capacity was reported by numerous writers. In the Bowery Bay plant described by Torpey (193), a newly developed process of thickening combined primary and activated sludges was used to obtain a dense sludge which was digested in a unit with a capacity of but 0.5 cu. ft. per

capita. The thickened sludge had a solids content above 10 per cent and was digested in a 31-day tank displacement period at loading rates of from 0.2 to 0.24 lb. volatile solids per cubic foot per day. At temperatures of 85° to 99° F., gas production was 1.7 cu. ft. per day per cubic foot of digester capacity. The volume of sludge was equal to that from conventional two-stage digestion at 2.1 cu. ft. per capita. With 6 per cent solids at loadings of 0.22 to 0.26 lb. volatile solids per cubic foot per day, digestion was satisfactorily accomplished in 15 days. Gas production dropped 14 per cent. Loadings of 0.125 lb. volatile solids per cubic foot per day are reported by Rohde (165) in Germany.

Wright (207) described plans for chlorinating excess activated sludge at Miami's new plant and holding it in concentrating tanks prior to digestion. In a British plant described by Bartlett (25) primary sludge is thickened in wells having a capacity of one day's sludge output. Bloodgood (35) pointed out the desirability of having solids concentrated as much as possible to conserve heat. Rankin (161) suggested that the trend toward a continuous process of sewage treatment might lead to a problem of continuous sludge disposal. Thickening ahead of the digester in such an operation could save heating costs of $2 to $3 per capita per year. A plant designed for Beaumont, Tex. (11), involves sludge thickening to 7.5 to 9 per cent, with a digester capacity of but 45 per cent of normal. Mortenson (148) described a patented process in which anaerobic sludge is mixed with crude waste before settling as a device for producing a more concentrated sludge suitable for anaerobic digestion. In the design of an unheated digester suitable for 10,000 to 100,000 population, Imhoff and Dahlem (107) proposed mixing digested sludge with fresh sludge before it enters the tank.

Griffin (86) described an aerobic digester patented in Britain in which wastes are introduced at the bottom, seeded with filter effluent, and drawn off digested at an intermediate level. Baxter and Horlacher (27) reported a new heat exchanger, in use in Philadelphia's Northeast plant, which avoids the troubles of other types. Sludge gas is burned in combustion chambers located on top of small sludge tanks approximately 12 ft. long, 5 ft. wide, and 2 ft. 8 in. deep. Hot gases are discharged downward into the sludge at high velocities and at temperatures of approximately 2,700° F. The result is turbulence of the sludge and effective heat transfer. Expanded gases at 125° F. are carried off in a vent stack and the heated sludge is pumped to digesters.

A need for sludge digestion in order to prepare it for disposal by dilution was presented by Rawn and Bowerman (162). Beneficial results listed include a reduction in the initial oxygen demand of sewage solids and the elimination of floating solids. In addition, the disease creating potential is drastically reduced, as demonstrated by results of a study which showed a 99.8 per cent decrease in coliform organisms during 30-day digestion at 95° to 100° F. Digestion radically alters the nature of material, rendering it amenable to rapid mixing and dispersion in water. Sludge digesters may be used as holding tanks, permitting discharge of sludge into favorable tides.

Effect of Other Materials

The effect of various materials on the sludge digestion process was discussed by a few writers. Klassen, Hudson, and Thomas (123) described the results of adding ground garbage to sewage from an institution. A digester designed for 3.5 cu. ft. per capita became overloaded with 0.91 lb. garbage per capita. At Elgin, Ill. (13), 75 per cent of the garbage from a state hospital was added to the sew-

age. Raw sludge increased from 5,830 to 9,250 gal., B.O.D. from 269 to 360 p.p.m., and gas production from 11,300 to 17,970 cu. ft. per day. Ross (166) concluded from experience at Richmond, Ind., that ground garbage can be satisfactorily digested with sewage. Good digestion was obtained, with no difficulty in starting digesters and no evidence of slowing down of digestion time. Dietz (61) reported that 1,000 p.p.m. of non-radioactive iodine had only a slight effect on digestion. Soluble non-radioactive phosphorus decreased gas production; radioactive phosphorus in concentrations up to 0.7 curie per liter had no effect on gas production. In another paper (12) the same author concludes that radioactive phosphorus in amounts that can be expected in sewage treatment operation does not affect normal sludge digestion. At Jackson, Mich., Greene (85) reported metal plating wastes interfering with digestion at times. Pienaar (158), in South Africa, reported difficulty with digesters into which 3 tons of inorganic solids, mostly lime, and 1½ tons of soluble protein from a gelatine factory flow each day. Deterioration of digested sludge was noted, causing an increase in sludge drying time from three days to four weeks. Pretreatment with combustion products of sludge gas is proposed.

Gas Production

Bloodgood (36) reviewed the production, composition, and use of sludge gas and pointed out that the decomposition of at least 97.5 lb. of organic solids is necessary to produce 1,000 cu. ft. of sludge gas. At Philadelphia's Northeast plant gas production was reported by Hoot (100) to average 1 cu. ft. per capita per day. The total amount of gas produced in 49 German cities was reported by Kiess (120) to approximate 554,000,000 cu. ft. per year. Backmeyer (22) described difficulties in getting gas production started in Cincinnati's new plant. Digesters were heated to 90° F. before adding raw solids, but the result was high concentration of volatile acids and a gas with 80 per cent CO_2. Starting without seed was considered a "complete failure." Seeding was finally used, but nine months were required to obtain proper digester functioning. On the other hand, Hanlon (89) found limed digesters starting under adverse conditions and reaching normal gas production in some three months.

Design

Requirements for sludge digestion have, as noted by Braine (41) changed in the past 20 years by reason of operational experience, development of heated digestion, and recovery of sludge gas. Ross (166) pointed out that the 10 cu. ft. per capita digester capacity used for sewage and garbage digestion at Richmond, Ind., should be sufficient, but is about the minimum under such circumstances. Klassen *et al.* (123) calculated from the overload of the digesters receiving garbage from the Dixon State School that their sludge capacity should be 8.5 to 11.3 cu. ft. per capita. Zack (211) reported satisfaction with 4 cu. ft. per capita sludge capacity for a small Imhoff tank installation receiving domestic sewage only. Imhoff (105) recommended that unheated tanks enclosed in earth embankments should be designed with a sludge storage capacity equal to three times that for heated tanks. Baumann and Babbitt (26) recommended that the sludge storage space in small tanks should be increased from 20 per cent of the total volume to at least 40 or 45 per cent, with a reduction in scum space. Hanson (90) reported 4 cu. ft. per capita as the design value for a new plant at Mayfield, Ky. At Jerome, Idaho, a plant completed in 1952 was reported by Ferrell (68) to provide digester capacity of 3.92 cu. ft. per capita.

A sludge capacity of 3 cu. ft. per capita was considered adequate by Calihan (47) for ten digesters and six Imhoff tanks at Dayton, Ohio. At Burlington, Vt., a plant completed in 1953 and described by Jones (113) provides 2.05 cu. ft. per capita, while the Hyperion plant at Los Angeles is described by Flood (73) as having a capacity of 2 cu. ft. per capita.

A British plant (25) providing sludge thickening ahead of the digesters is designed for 1.5 cu. ft. per capita storage in primary digesters, and 1.25 cu. ft. per capita in secondary digesters. A reduction in necessary sludge storage capacity is indicated for high-rate digestion. Rankin (161) suggested, however, that state agencies may be slow to reduce capacity reqirements until more evidence has been presented.

The design of digesters in Germany was described by Rohde (165). Deep digesters (on the order of 75-ft. diameter by 77-ft. depth) were noted. Heating of older plants was by means of fixed or revolving coils, but newer plants use steam injection, outside heat exchangers, or a double-walled hot-water cylinder in the center of the tank. In small digesters low-pressure steam (7.35 p.s.i.) is injected through nozzles located 6 to 10 ft. below the surface of the sludge. In large digesters steam at 59 to 118 p.s.i. is used. Cylinder heaters are designed for 61.7 B.t.u. per sq. ft. per hour per ° F., but this value may fall to 10.3 due to incrustation which is difficult to remove.

The use of simple unheated digesters was reported from various parts of the world. Askamit and Mazurkiewicz (4) reported that small prefabricated modified Imhoff tanks such as used in Poland did not give satisfactory results. Arenander and Okun (19) reported an unheated digester used in Ciudad Piar, Venezuela; Peter (157) described an Imhoff tank built for Tiberias, Israel; and Le Bosquet and Ludwig (131) noted the use of open digesters in the Belgian Congo. Suryaphrakasam (188) reported that Imhoff tanks are used for digestion in India because of a lack of locally manufactured machinery. In India's climate a sludge storage capacity of 1 cu. ft. per capita is sufficient.

Leadville, Col., located at an altitude of 10,140 ft., required special treatment of its digester. Boyce (40) noted that heating pipes were installed in the digester walls and that 2 in. of spun glass covered with cement stucco was used as insulation.

Operation and Maintenance

The need for close control in digester heating was stressed by Calihan (47). He reported that internal heating coils in digesters at Dayton, Ohio, have been satisfactory since 1938 under operation at 80° to 90° F. Nevertheless, sludge incrustation requires water temperatures up to 130° F. and makes periodic cleaning necessary. Cleaning of coils requires one to three weeks. In heat exchangers, sludge caking in the coils was reported as negligible in six years. At Beaver Falls, Pa. (17) incrustation of heating coils produced a sludge temperature fall of 75° F. One-quarter inch of scale was found to weigh 20 tons. At Jackson, Mich. (85) a 4-year accumulation of sand was sufficient to imbed the heating coils and make digester heating difficult, while at Washington, D. C. (74), one-third of the tank capacity was lost to sand and scum.

Starting of digesters after cleaning or for the first time was discussed in the literature. Bloodgood (35) advised that seed be used whenever possible. The seed and liquid in the tank should be heated to 80° to 90° F., and raw solids added at about 10 per cent of the final rate. As control tests, the gas should be analyzed and the gas volume measured daily. Attempts to

start digesters without auxiliary heat (100) resulted in acid production and no gas. Heated digesters (80° F.) charged with raw sludge produced gas in five to six weeks. Similar digesters seeded with digested Imhoff sludge, however, produced methane in three or four days. At Detroit (9), digesters restarted with seeding sludge produced gas in seven days. Foaming was evident for a few days, but subsided when feeding was stopped for 11 days. During the 11-day period gas production increased. When raw solids feeding was resumed, gas production dropped off briefly, but in two weeks was up to normal. Extreme difficulty in operating digesters at Oceanside, Calif. was described by Sampson (169). Prechlorination at 19 p.p.m. was thought to have an adverse effect, but this was not demonstrated. Tests showed that the scum contained as much as 164 p.p.m. chromium. A small increase in gas production was noted after addition of 3,000 lb. of ammonium sulfate and 700 lb. of lime, but the increased sulfide gas caused corrosion and increased odor. Addition of 200 lb. of trisodium phosphate had no effect in breaking up the scum. This was finally accomplished by the use of an activator made of supernatant liquor in which animal and vegetable wastes had been digested. Lime was added and gas production eventually increased.

Meers (143) reported difficulties in removing heavy sludge during cleaning of a digester. Sodium hexametaphosphate pumped into the tank led to a breakup of this sludge so that it was readily pumped out. A number of other difficulties were cited by Yenchko (210). In one instance a digester had to be emptied three times in one year; in another, foaming was corrected by adding vacuum filter filtrate to raise the pH. One case was noted in which satisfactory operation of an Imhoff tank was obtained by recirculating its contents by means of a pump inserted into the sludge draw-off line.

Bloodgood (34) pointed out that foaming can be combatted by maintaining a maximum amount of ripe sludge in the digester during cold periods, and further suggested (35) that care be taken not to draw off too much digested sludge at one time. Morgan (147) noted a close relationship between gas production rates and volatile acid concentration, and called attention to the value of volatile acid determinations in the control of sludge digestion. Volatile acid determinations can be used to determine the amounts of lime necessary to maintain a satisfactory buffering system within the sludge mass. This was noted by Sawyer, Howard, and Pershe (171) in reporting studies on liming of digesters. Laboratory studies with primary sludge and with a mixture of primary and activated sludge showed that the addition of lime is a practical means of relieving a "stuck" digester. Lime additions in amounts equivalent to 25, 50, 75, 100, 150, and 200 per cent of the volatile acids, expressed as acetic, were found to have desirable effects which were in direct proportion to the amount of lime added, the highest percentage giving the best results. Dosages of lime as great as 21.75 tons of hydrated lime per m.g. of digesting sludge were used with beneficial results. pH levels were raised to 10.0 by batch addition of lime without adverse effects.

An unusual failure of a digester was reported by Vaseen (199). The tank, designed for 2.5 cu. ft. per capita when heated, was operated as a cold digester serving some 6,000 people. Wastes from the slaughter of about 100 animals per day produced a 6- to 8-in. thick fibrous scum blanket of straw, hair, manure, and other materials. This blanket was too tough for skimming arms to remove and blocked the supernatant overflow. Continued introduction of raw sludge

caused the fixed cover of the digester to fracture.

Fly breeding on open digesters was controlled by Wells (204) in San Antonio, Tex., by spraying the surface with methoxychlor and malathon.

Sludge Disposal and Utilization

Disposal of Digested Sludge

At Marshall, Mo., Hayob (93) described the use of a 2-ton dump truck equipped with a 1,625-gal. removable tank for spreading wet digested sludge on farming land. An unloading dock and pipe roller are used to load or unload the tank from the truck. Filling, venting and discharge openings are provided for the tank. The drying bed walls at this plant were built too high for satisfactory evaporation of moisture from the drying sludge and no means for truck removal of the cake inside the beds was provided. The long drying time, labor cost, and insect breeding which occurred in the sludge cake resulted in the shift to wet sludge disposal. The implications are that sludge beds should be designed with low side walls and truck runways. Insect breeding is not normally a problem with properly digested sludge. Hayob does not mention the health precautions observed with liquid sludge disposal, but presumably its use is restricted to crops grown above the ground or cooked before eating. The hazard of personal contacts with wet sludge by the public also deserves consideration.

Rawn and Bowerman (162) presented an interesting case for the disposal of wet digested sludge by dilution into large bodies of water. Digested sludge because of its humus properties is amenable to rapid mixing and dispersion in water. The disease-creating potential of digested sludge is also greatly reduced over raw sludge. The authors report tests showing that 30-day detention in a digester at 95° to 100° F. reduces the coliform density per ml. from 1,500,000 organisms to 3,000. Likewise, the B.O.D. of digested sludge appears to be about 10 per cent of raw sludge. Digester scum, which might cause floating solids in bodies of water, would not be discharged to streams. Scum that does not ultimately digest could be incinerated or buried. Discharge of wet digested sludge could be controlled to take advantage of favorable currents or tides or discharged in off-season bathing periods. When sludge disposal by dilution will effect an economy in operation when compared with conservation, the authors feel the problem becomes solely a matter of analysis of the particular geographical or oceanographical factors at hand. Discharge of digested sewage sludge with a primary effluent through a common outfall may reasonably be accomplished, in almost all instances where primary effluents are now being adequately disposed of to lakes, rivers or oceans. Separate sludge outfalls may be required in some cases to meet health and safety standards. The favorable conditions existing for digested sludge disposal by dilution at Portland, Ore. and the Los Angeles County Sanitation Districts joint disposal plant are cited. This method of disposal requires careful consideration of the local conditions and the increasing need for secondary treatment of sewage in many locations also would militate against its use.

Sludge Drying and Incineration

At Dayton, Ohio, Calihan (47) speeded digested sludge drying on sand beds with sludge high in grease content by recirculating the sludge back to the primary settling tanks, settling, and then withdrawing it again to the sludge beds. In effect, the sludge was elutriated. The drying rate for the glass covered sludge beds averages 17 lb. of dry solids per square foot, whereas the open beds dried 16 lb. per square foot per year. The

sludge is applied 10 in. deep. The sludge cake is given additional drying with a multiple-hearth furnace operated at 300° F. temperature. Sludge gas is the source of heat.

Babbitt (21) attempted drying sewage sludge under pressure in the hopes of releasing retained molecules of water. The sludge was placed in a pressure "gun," where upon sudden release it was discharged into a "target" receptacle and then to a sand drying bed. The nature of the water molecules was such, however, that no rearrangement occurred to release "bound" water. He concluded that the method was not a practical or economical procedure.

Kilborn (121) reviewed the problem of heat drying of activated sludge.

Allan (5) reviewed the history and present practice of sludge incineration.

Sludge Utilization

Further progress is reported in producing Vitamin B_{12} concentrate from the processed sewage sludge, Milorganite (16). A pilot plant has been constructed and is now in continuous production. The results are said to exceed expectations, both as to quality and quantity. Samples have been furnished potential users for a supplement to animal and poultry feed. Over 60 tons of Milorganite have been processed to date. The vitamin extraction process does not alter the fertilizer value of Milorganite in any way.

Rawn and Bowerman (162), while not discounting the value of sewage sludge as a soil builder, point out that composting of all organic refuse from a community may afford 10 times the humus production of sewage sludge alone, and therefore suggest the need of evaluation of the total municipal refuse picture. If methods for composting of garbage and other municipal refuse are better developed, more consideration will undoubtedly be given to fuller utilization of all municipal wastes.

A method of disinfecting sewage sludge to be used as fertilizer was developed by Keller and Hide (118) on a laboratory scale at the National Chemical Research Laboratory of South Africa. Digested sludge is heated to 55° C. for 2 hr. This process kills the eggs of parasitic worms, such as those of *Ascaris lumbricoides*, which may occur in numbers up to 260,000 per liter of crude sludge at the sewage works of Johannesburg.

Skulte (178) presented a provocative discussion on the use of raw sewage for crop irrigation. European experience and practice are cited. The increasing need for water and soil conservation in this country is stressed and a strong case presented for utilizing sewage for these purposes.

Composting of municipal wastes was discussed by Husband (104). Present status of the composting process in the U. S. was reviewed by a committee of the Sanitary Engineering Division, American Society of Civil Engineers (7).

A number of materials such as garden soil, horse manure, partially decomposed organic material, and a commercial preparation of special bacterial cultures were tested for their seeding value in composting of garbage (83). No measurable effects were detected due to these additions. They were considered as superfluous.

The composting of garbage in open piles at Baden-Baden is described by Straub (185).

Composting of Municipal Wastes

Golueke and Gotaas (82) reported on composting of municipal refuse with and without sewage sludge. The history and status of composting methods are outlined. The procedure developed by the authors consists of grinding, stacking, aeration by turning, and regrinding. Windrows from 5 to 6 ft. high and any convenient

width were used for stacking the ground refuse. Compost was produced by aerobic thermophilic microorganisms in 10 to 20 days. No inoculums were required. Temperatures in the 70° to 75° C. range persisted from 3 to 6 days, during which, with proper turning of material, pathogens and insect eggs, larvae and pupae were destroyed. The final product had many characteristics beneficial both to the soil and to growing vegetation.

Van Kleeck (198) in a discussion on fertilizer value from general waste disposal methods comments on the additional humus material available for soil fertilization from home garbage grinding.

Raw Sludge Oxidation

Abel, Moran and Ruof (2) experimented with the oxidation of raw primary sludge using oxygen gas or air at temperatures of 150° C. and higher and pressures of 300 p. s. i. and higher in a rocking autoclave. The process is similar to that used for the oxidation of coals. At the lower temperature and pressure using oxygen, less than 10 per cent of the initial carbon was converted to CO_2, but the slimy character and fecal odor of the sludges were completely destroyed, which should make utilization or further treatment less objectionable. At higher temperatures and pressures, less than 1 per cent of the initial carbon remained in the insoluble residue. Furthermore, the volatile solids were almost completely destroyed. The heating of the large quantities of water and oxygen required is admittedly a serious obstacle to economic operation, but with suitable heat exchange equipment and perhaps at even higher temperatures and pressures than those used, heat could be recovered, the holding time could be lowered, and the size of the oxidation equipment materially reduced.

Sludge Elutriation

Sparr (180) gives data on practical operating experience with digested sludge elutriation at the Bay Park sewage treatment plant at East Rockaway, N. Y. A minimum detention of 12 hr. for the washed sludge in the elutriation tank is required for satisfactory concentration. Low solids content of the elutriated sludge increased the amount of coagulant required to condition the sludge and reduced the filter yield. The wash-water ratio plotted against the alkalinity of the elutriated sludge shows that little is gained by wash-water ratios higher than 5:1. The volatile matter content of the sludge determined the operating economy of elutriation and vacuum filtration. This relation has been found to hold true at practically all plants employing these processes. Simple formulas are presented for determining the dosage of ferric chloride required for vacuum filtration, and for determining the alkalinity of the washed sludge based on the original alkalinity of the sludge to be washed, the alkalinity of the wash water, and the water-water ratio. A modified sludge factor was developed showing the relationship between the quality of the elutriation tank effluent and the dry solids loading, volatile content of the sludge, and the liquid detention time.

Vacuum Filter Cloth Life

At Baltimore, Md., Keefer (116) reports over 4,000 hr. use from wool filter cloths. Ferric chloride only is used for sludge conditioning. Each cloth is cleaned for about ½ hr. every 8 hr. with a low-pressure water spray. When this fails to clean a cloth, it is then cleaned with a shade-tree sprayer with water under high pressure. When cleaning under high pressure, the filter is rotated slowly with the sprayer nozzle about 5 or 6 ft. from the filter. The spray is not directed too long on any one part of the cloth to

avoid cloth injury. A badly blinded cloth usually can be cleaned in 4 or 5 hr. by this method. The spraying equipment consists of a pump delivering 22 g.p.m. at a pressure of 700 to 900 p. s. i. The equipment is reported as paying for itself many times in view of the present cost of wool filter cloths.

Mechanical Equipment

A new series of articles by Carter and Karrassik (48) covering design, construction, and maintenance of centrifugal pumps supplements the articles by these authors that have been reviewed in previous years. Types and classifications, pump casings, and pump impellers are the subjects of the first three articles presented. The economics of pump operation are discussed by Cromwell (57), and a nomographic chart for calculating power cost savings and capitalization amounts is presented.

Included among the articles on equipment and practice in sewer maintenance are those by Appel (8) and Schneider (173). A preventive maintenance records system is presented by Sanders (170).

Metallizing of equipment by spraying melted metal on prepared surfaces is discussed by Skorczeski and Douglas (177). At the Marshalltown, Iowa, plant all iron pipe and fittings were prepared and metallized in 1946 at a cost for materials alone of about $0.23 per square foot. Since that time no further corrosion or pitting has been noticed. Final clarifier mechanism was metallized in 1946 and 1947, and no further corrosion was indicated as of 1953. Materials cost for this work was about $0.17 per square foot. The equipment required and the hazards involved in the metallizing procedure are discussed.

A wiring diagram and description of a shop-made electrode assembly in a wet-well for "follow-the-flow" pump operation is presented by Coppa (53). Difficulty with fouling of electrodes for sewage pump controls led to the design of a "trouble-free" assembly described by Studley (186). The unit consists of a plastic tube to which is attached a flexible plastic ball filled to the proper level with fresh water. The ball is submerged near the bottom of the wet well. The fresh water rises in the tube to the same level as the sewage in the wet well as the ball is compressed. The electrodes are set in the tube to the levels desired for starting and stopping the pumps.

A number of the papers presented at a conference on instrumentation have appeared in the literature. These include a review of the various types of automatic control valves, giving specific valve use selection and methods of sizing valves (135), equipment for ammonia feed control (44), and others (152)(23).

The design of a continuous automatic sampler for deep sewers is presented by Wilkenfeld (205). The unit consists of a deep-well pump so arranged as to pump a continuous stream of about 5 g.p.m. from the sewer. A sample cup, actuated by a motor, passes through the liquid stream and is tripped automatically, discharging its contents into a collection bottle. Excess flow is returned to the sewer through a drain. Sample size can be adjusted by changing the cup size, and frequency of sampling by varying the speed of the motor actuating the cup.

Of interest to operators is a description of several gadgets for plant operation described by Lohmeyer (134).

Detergents

Ainsworth (3) briefly reviewed the mode of action, classification, usage and determination of synthetic detergents.

Croft and Faust (56) employed the methylene-blue colorimetric method to determine the concentration of anionic detergents in sewage at the Hagerstown, Md., disposal plant over a 7-day period. The highest concentration (6

p.p.m.) of detergent was observed on Monday and the low concentration (0 p.p.m.) appeared on Thursday. A brief study of detergent concentration through the plant indicated that a portion of the detergent was removed by sedimentation and the trickling filter.

Thomas (192) presents predictions of the effects of synthetic detergents (in ratio of 3 parts detergent to 1 part of soap) on military sewage based on trends and relevant experimental evidence involving detergent usage. The author estimates a 5 to 15 per cent reduction in B.O.D.; a 5 to 15 per cent reduction in suspended solids; and a 15 to 25 per cent reduction in grease in sewage. He believes that the B.O.D. removal in primary treatment will decrease from 20 to 35 per cent, with a corresponding increase in the loading of secondary units. Also, a reduction in the amount and fuel value of gas from the digestion of detergent substituted sludge may be anticipated. Thomas points out that problems of special treatment may arise because of the fertility of receiving waters due to polyphosphate builders, interference with water treatment by detergents not removed by sewage plants, and the poor degree of treatability of many synthetic detergents used in commercial laundries.

Degens and co-workers (58) reported no adverse effect of Teepol (a secondary alkyl sulfate) or Lissapol N (a polyglycol ether of an alkylated phenol) in concentrations of 25 to 75 p.p.m. (active matter) on the quantity and volume of sludge from raw synthetic sewage.

Bogan and Sawyer (37) presented the results of biochemical decomposition of 16 out of 36 synthetic detergents studied. The authors conclude that all the principal anionic and nonionic synthetic detergent types are susceptible to some degree of biological degradation. The susceptibility to biochemical decomposition varies among the different detergent classes and among members of the same chemical type. Also, biochemical stabilization proceeds at a relatively slow rate for alkyl aryl sulfonates, alkyl phenoxy polyglycols, and derivatives of high molecular weight polyethylene glycols.

Edwards and Ginn (63) have modified the two-phase titration method of Barr for determining anionic detergents in sewage. The authors minimized the interference by soap and proteins by adjusting the pH to 7.0 to 7.5 during the reaction. Interference from calcium and magnesium salts was overcome by using disodium ethylene diamine tetra acetic acid. The method was not affected by NaCl or Na_2SO_4 in concentrations up to 1,000 p.p.m. Thiocyanates, nitrates, nitrites, and urine did not influence the results. Either brom phenol blue or azo phloxine can be used as the end-point indicator.

Lynch and Sawyer (36) investigated the frothing of 11 retail synthetic detergents and their influence on oxygen transfer during aeration. The detergents in concentration of 50 p.p.m. (total product) was added to tap water and aerated at 25° C. The frothing ability of the detergents varied markedly and the rate of transfer of oxygen during aeration was reduced. A wide range in the degree of reduction of oxygen transfer was evident.

Degens (59) has brought together information from 18 references (previously reviewed in THIS JOURNAL) concerning the occurrence, the cause, and the suppression of froth in sewage treatment plants.

Martin (39) reviews the cause and control of detergent frothing and cites 18 references.

Lagooning, Irrigation and Reclamation of Sewage

Van Heuvelen and Svore (197) discussed the experiences with sewage lagoons in North Dakota. Most lagoons in North Dakota are designed with a holding period of 120 days so

that evaporation and absorption provide the final disposal of the sewage. Approximately a 10-acre lagoon area is provided for each 1,000 population. No pretreatment is required. Results from a number of lagoons show that in such large lagoons sludge accumulation and removal is not a problem.

Sewage disposal by lagooning is also discussed by Ellison and Smith (66). In the Southwest, pre-settling and chlorination are provided prior to discharge into lagoons. Another general discussion of this subject is presented by Shaeffer (172).

Renn (163) approached the problem of oxidation ponds from the standpoint of algae production and nitrogen conservation. A study of algal physiology with special emphasis on radiochemical study of their ion accumulating characteristics was made by the University of Texas (196).

Reclamation of sewage effluent by spreading into basins was studied by Greenberg and Thomas (84) at Lodi, Calif. From settled or more highly treated effluents a bacteriologically safe water could be produced by percolation through 4 ft. of fine soil. The rate of percolation depends on the degree of treatment prior to spreading. If the liquid applied to spreading basins does not contain high concentrations of undesirable wastes, a water of satisfactory chemical quality can also be produced. Additional data were presented by Butler, Orlob and McGauhey (45). The removal of suspended organic matter was accomplished in the first 0.5 cm. of the soil regardless of effective size of soil, with no tendency for the accumulated organic material on the surface to migrate downward. The chemical nature of percolating sewage is not altered materially by passage through 13 ft. of soil provided the chemical in question is not subject to biochemical change. Where the ground-water table is near the surface of the spreading basin, coliform organisms can enter into the ground water. When the chemicals enter the ground water they will be subject to dilution. A municipal sewage treatment plant effluent after suitable treatment has been used in Texas for the production of steam, make-up water in cooling towers, and engine cooling (141).

Sewage effluent disposal experiments through crop irrigation were reported by Henry *et al.* (94). The purpose of this 3-year study was to determine how much effluent could be disposed of by this method and the benefit of irrigation in crops. On the soil on which packinghouse waste effluent was applied, 40 in. or more could be applied to a crop of Reed canary grass during the growing season. The crop and the soil removed virtually all the nitrogen and phosphorus from the percolating water. The crop yields were substantially increased by the nutrients in the applied waste. Webster (203) reviewed the practice of disposal of cannery waste effluent at Seabrook Farms, N. J., by spray irrigation into a wooded area since 1950. Mather (140) also reviewed the experiences with woods irrigation of Seabrook Farm wastes. Hunt (103) reviewed the practice of sewage irrigation.

Sulfides, Odors, Corrosion and Control

The microbiological process resulting in formation of sulfides was discussed by Butlin and Postgate (46). Gilchrist (79) affirmed that bacterial action is responsible for the conversion of sulfides to sulfuric acid with the resultant corrosion of the concrete. According to Stutterheim and Van Aardt (187) rising mains carrying centrifugally-pumped sewage are chief sources of the H_2S. Efficient methods of preventing entry of this gas into gravity sections are required for the prevention of corrosion. Wherever high concentrations of H_2S occur, acid cleaning and chlorination should be resorted to. Sewer ventilation or sewer

aeration is not very effective. In new sewers, corrosion of concrete may be eliminated by making the rising mains as short as possible, by eliminating turbulence in gravity sections, and by using concrete made with limestone or dolomite aggregate plus a bactericide.

In a contaminated pond producing hydrogen sulfide, Schulze (176) was able to control odors by sodium nitrate treatment. Nitrate treatment of sewage by the addition of nitrate-rich effluent from trickling filters or from activated sludge was suggested by the same author (175).

By adding nitrates to sewage and filter effluent, Stones (183) was able to show that the reduction of nitrate did not result in an increase of ammonia and, therefore, the reduction went to nitrogen gas giving a 2.5 equivalents of oxygen for every part of nitrate nitrogen reduced.

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RADIOACTIVITY

General

Revisions were made in the recommendations of the International Commission on Radiological Units at the 7th International Congress of Radiology, Copenhagen, Denmark, in July, 1953 (49). The major change was the establishment of the "rad" as a unit of absorbed dose imparted to matter by ionizing radiation at the place of interest. One rad is equal to 100 ergs absorbed per gram of material.

Concerning tolerance levels, Morgan and Ford (80) derived maximum permissible levels of radioisotopes for single exposure and for body excretion with either chronic or single exposure. Exposure to the gastro-intestinal tract was frequently found to be critical. As a result some MPC values were lowered by large factors. The results obtained from examining human bone marrow (46) suggest that the tolerance dose for inhaled radon ^{222} (plus daughters) should be 10 to 100 times lower than the present value, which is based on roentgen and gamma ray exposure.

On the other hand, new studies on the toxicity of plutonium ^{239} (6) indicated that the maximum permissible concentration in drinking water could be raised. If this were done, savings in both time and money could be made in treating the effluents of the Hanford plutonium works.

Natural Background

Background values of natural airborne alpha activity were determined over a period of nine months by Mercer (74). Average values for RaA and ThB deposited on membrane filters were found to be 0.13 and 0.0052 $\mu\mu$c. per l., respectively.

Hursh (48) determined the radium content of raw and finished water samples of 41 U. S. cities. Eight of the cities were supplied with well water having a radium content varying from 0.027 (Phoenix, Ariz.) to 6.55 (Joliet, Ill.) $\mu\mu$g. per l. of raw water. Except for the Allegheny, Missouri, and Mississippi rivers, which had 3.7, 1.77, 1.08, and 0.425 $\mu\mu$g. per l. of raw water at Pittsburgh, Omaha, St. Louis, and New Orleans, respectively, the radium content of surface water was less than 0.2 $\mu\mu$g. per l. Except for the Joliet, Ill., supply, the radium content of tap water was found to be less than 0.2 and usually less than 0.1 $\mu\mu$g. per l.

Flores (30) reported the natural radioactivity of 17 Central American spring and well waters varied from 11 to 1,875 $\mu\mu$c. per l. The minimum values were found in the waters near San Jose, Purua, and the maximum value was found in the El Penon water near Mexico City.

Trembaczowski (106) found the radioactivity of Slavinek Springs near Lublin, Poland, was 1.12 to 1.43 Mache units. These values are of the same magnitudes as those of other resort springs.

The natural background alpha radioactivity of rain, surface and hot spring waters has been determined by a number of investigators, as follows:

Location and Kind of Sample	Radioactivity Measured		Ref.
	Kind	$\mu\mu$c./l.	
Arkansas, streams	Rn	8.4–1,070	(8)
Arkansas, lakes	Rn	<1–123	(8)
Arkansas, well	Rn	58,750	(8)
U. S. and Japanese, rain	Rn	<10	(63)
U. S., hot springs	Rn	100–3,000	(62)
U. S., cold springs	Rn	100–7,300	(62)
Japan, Masutomi, spring	RaC′	>1,000,000	(63)
Japan, Masutomi, rain	RaC′	15,000–34,000	(63)
Japan, Tokyo, rain	RaC′	5,000–25,000	(63)
Spain, natural waters	Rn	370–174,000	(96)

Libby (68) reported results of assays for the natural tritium content of rain, surface waters and wines of different vintages from various locations.

The amount of radioactivity in air was measured from April to September at altitudes from 1,460 to 3,500 meters by Garrigue (33). The tabulated results showed well-defined invasions of activity on August 15, August 28, and September 5, 1953.

Terrill, Ingraham and Moeller (105) reviewed the natural occurrence of radioactivity in water, minerals and organic materials in the U. S. as related to toxicity for man. Both medical and industrial uses are discussed for radium and its decay products.

Techniques in use are reviewed as a potential or real health hazard. More than 200 per cent of the maximum tolerable concentration has been detected in industries using luminous paint processes and mining operations.

Fall-Out

Measurements conducted by Santomauro (94) between February 1951 and November 1952 showed that nuclear weapon tests at Las Vegas, Eniwetok and Montabello were followed one, two and three weeks later, respectively, by an increase in the radioactive content of rain and snow falling in Italy. From March 19, 1953, until the middle of June, the atmospheric radioactivity was measured by Haxel and Schumann (45) at Heidelberg, 565 m. above sea level. Diagrams show the amount of radioactivity found. The amount of radioactivity over the Parisian area increased with the Nevada tests of March to June, 1953, and with the Russian tests in September, according to Abribat and Pouradier (1).

Kilcawley *et al.* (59) reported a study made on the radio-activity of rain and the water in several reservoirs in the Troy, N. Y., area from May 15 to August 31, 1953, following the detection of considerable rain-out during a storm on April 26. The reservoir waters usually contained a beta activity of 10 to 100 $\mu\mu$c. per l. as compared to a beta activity of 200 to 30,000 $\mu\mu$c. per l. in the rain.

Nader, Goldin and Setter (82) determined the beta radio-activity of precipitation in the Cincinnati, Ohio, area for 12 months beginning in March 1953. The background level of 30 to 80 $\mu\mu$c. per l. prior to March 18 increased to a maximum of 319,000 $\mu\mu$c. per l. on April 29. The rain-out was identified by decay data as mixed fission products usually corresponding to the age of specific bomb bursts. It was estimated that a total of 13.5 c. of activity fell per square mile between March 18 and July 25. The accumulated rain-out would have decayed to 0.15 c. per sq. mi. by December 10, 1953.

From a study of the radioactivity of surface and treated waters of the Cambridge and Lawrence, Mass., and Rochester, N. Y., water supplies in April-June, 1953, Bell, Thomas and Rosenthal (13) concluded that only approximately 55 per cent of the 2 to 30 day-old bomb debris found in surface water was removed in passage through rapid sand filtration plants. A lesser percentage (4 to 40 per cent) of residual debris of greater age was removed.

Garrigue (34) measured the radioactivity on Puy-de-Dome, France, and in the air above it from October 10 to November 3, 1953. It was concluded that all radioactivity found was from cosmic radiation.

Van Middlesworth (110) tested the I^{131} in thyroid samples of cattle and sheep from Tennessee, Massachusetts, and Oklahoma collected in June and July, 1953. The activity found varied from 4,400 $\mu\mu$c. per g. of tissue in June 12–14, to 60 $\mu\mu$c. per g. in July.

Fall-out estimates of the predominant chemical species resulting from a shallow underwater burst of an atomic bomb were given by Bunney and Ballou (18). It was predicted that the halides, alkali metals, and alkaline earth metals should appear as ionic species in their normal valence states. Several other elements (for example, P, S, Ge, As, Mo, Tc and Te) should occur as oxygenated anions and nearly all of the remaining elements (for example, Ce, Nb, Ru, Y and Zr) should exist as oxides or hydrated oxides associated with collodial or gross particulate matter (41).

Contamination and Decontamination

Coleman and Silverman (22) studied radioactive particulate matter and gases from reactors. Suitable ventilation controls for these radioactive materials include removal of particulate

matter from incoming air, the use of reduced pressures to prevent leaks, induced air flow toward "hottest" areas, and dilution. Decontamination processes use filters, settling chambers, electrostatic precipitators, wet collectors and high stacks for dilution. Leary, Clark and Hammond (65) presented performance data on a wet cell glass-wool filter designed for the removal of radioactive particulates from air.

The maximum possible hazard from a nuclear incident, in which all of a reactor's radioactive contaminants are dispersed into the air, was evaluated by Mesler and Widdoes (75). This evaluation considers external, inhalation and fall-out doses and suggests steps which can be taken to reduce these hazards. The successful restoration program following an accident at Chalk River was described by Gilbert (36). The reactor had released several thousand curies of fission products into the building and onto equipment.

A similar problem of decontaminating a high-level chemistry cell was described by Coplan and Smith (23). Comparative decontamination tests on stainless steel contaminated with Hanford U dissolver solution were reported by Kattner (53). Sandblasting was considerably more thorough than the usual chemical method. Sandblasting not only reduced the decontamination time, but also removed over 99 per cent of the contamination.

The extent of surface contamination by uranium and radium in connection with ore refining was evaluated by using G-M survey meter readings with and without the gamma shield (9).

Surveys and Water Treatment

The comprehensive monitoring service at the Hanford Works (5) indicated that the problems of disposing of airborne and solid radioactive isotopes, as well as those in water solution or suspension, were carefully worked out and that no hazards to human health have occurred. From a study of the radioactivity of the Columbia River below the Hanford reactors, Foster and Rostenback (31) concluded that since the levels of activity are well below one-tenth of the maximum permissible concentration, "no health hazards to users currently exist. Even if game fish were caught in the most radioactive section of the river, a person could eat 20 lb. daily without exceeding permissible radioactivity limits." Tests were reported by Brockett and Placak (14) on the retention of radioactive wastes in shale by percolation through small columns and by shaking with clay suspensions. Under laboratory conditions 98 to 100 per cent of Ba^{140}, Ce^{144}, Cs^{137}, P^{32}, Ru^{106}, Zr^{95} was removed. Only 80 per cent of the Sr^{90} was removed. An increase in dosage of shale from 1,000 to 40,000 p.p.m. affects removal very little except with Sr^{90} and P^{32}. Base exchange ratings do not necessarily indicate the removal effectiveness. Chemical form of the isotope affects removal.

Clinch River (Tenn.) water with added radioactivity and with or without various clay and silt additions was used by Goodal, Gloyna and Carritt (19)(40) in a study of coagulation with ferrous sulfate, lime and phosphate for the removal of strontium and mixed fission products. Depending on the kind of contaminant and on the kind and amount of chemical agents and the pH of coagulation, the removal achieved varied from 60 to over 95 per cent.

The fate of radioactive strontium during the treatment of water by conventional process was investigated by Downing, Wheatland and Eden (27) and reviewed by Southgate (98). Only a small portion of the activity was removed during chemical coagulation as normally carried out. A higher proportion was removed when a very large dose of coagulant was added, and during softening by chemical methods. Softening by ion exchange removed over 97 per cent of the activity.

In studying the capacity of the lime-soda water softening process for the

removal of radiostrontium from water, McCauley, Lauderdale and Eliassen (73) found that coprecipitation with calcium as a mixed carbonate crystal gave maximum removal. By use of the process it was possible to reduce the strontium activity from 200 counts per second or higher to near background. Eden, Elkins and Truesdale (28) investigated the removal of the radioactive nuclides, Sr^{90}, Ru^{106}, I^{131}, Cs^{134}, Ce^{144} and Pu^{239}, from water by slow sand filtration and by activated sludge sewage treatment. The removal by slow sand filtration was relatively high at first until equilibrium was reached in 0.5 to 5 or more days, depending on the isotope. At equilibrium very little of the Sr^{90} and Ru^{106}, about 50 per cent of the I^{131}, 90 per cent of the plutonium and over 99 per cent of the Ce^{144} was removed. The activated sludge studies consisted of adding an isotope to activated sludge (5,000 p.p.m. suspended solids) grown on nutrient solution. The mixture was aerated for 200 hr. Samples were collected periodically, centrifuged, and the clear liquor tested. The uptake of activity generally increased with time and depended upon the pH of the sludge mixture. The uptake after 2 hr. aeration was greatest at pH 7 to 10 for Sr^{90} and mixed fission products three years old, high for cerium over a pH range of 2 to 10, high for plutonium (over 90 per cent removal at pH less than 7, but only 40 per cent at pH 10), low for Ce^{134} (but greatest at pH 9 to 10) and least for Ru^{106} (less than 15 per cent over the entire pH range).

Additional studies by Straub and Krieger (101) and Lacy (64) show clay suspensions (2,500 to 5,000 p.p.m.) are capable of removing about 90 per cent of the added Co^{60}, Zn^{65}, Se^{75}, Ta^{182}, Ir^{192}, Tl^{204}, in a 30-min. contact time and that a dose of 1,000 p.p.m. clay is quite effective for removing Ce^{141}, Ce^{144} (Pr^{144}), Zr^{95} (Nb^{95}), Ba^{140} (La^{140}) and Sr^{90} (Y^{90}). Clay was less effective for Ru^{106} (Rh^{106}) and very poor for I^{131}. The removal was not affected by calcium concentration, but improved when the pH was greater than 5.

Treatment and Disposal

Studies were made by Klein, Greenberg and Kaufman (56)(57) on the removal of mixed fission products and radioactive strontium from both domestic sewage and synthetic sewage substrate. The activated sludge and trickling filter processes were found to remove from 70 to 85 per cent of the fission products one to three years old. Versene in sewage caused the elution of fission products from trickling filter slimes. Generally, the removal of strontium did not exceed 20 per cent and was dependent on the mineral composition of the sewage substrate.

Steel and Gloyna (100) operated sewage oxidation ponds with associated algal growths for the removal of radioactivity. The most effective way of separating radioactive-contaminated organisms and associated debris from oxidation pond effluent was found to be by filtration of the suspension through a diatomaceous earth cake. The cost of diatomaceous earth was about 15¢ per 1,000 gal. of algae-water treated. The filtered effluent was clear, free of color and suspended matter. Chemical precipitation and settling with subsequent filtration of the chemical sludge was expensive and removal was not as effective as vacuum filtration through diatomaceous earth.

Clark (21) described the waste disposal and decontamination laundry facilities at the Livermore Research Laboratory. Studies on the removal of radioactivity from laundry wastes by the activated sludge process and by slime organisms, were reported by Reading *et al.* (90) and Gloyna (38) (39), respectively.

The design and process efficiency of a kilocurie waste gas and liquid processing and disposal plant was described by Leary, Clark and Hammond (66). Provisions were made for stor-

age and handling of high-level gamma-emitting liquids, dusts, and fumes, typical of wastes from a radiochemical processing laboratory. Separate waste streams for alpha-emitters are employed. Design capacity of the system is 2 g.p.m. of liquid and 30,000 c.f.m. of air.

A decontamination factor of 500 was obtained by Lowe *et al.* (71) by chemically precipitating radioactive process wastes with a one-cycle ferrous sulfide, $Fe(OH)_2$, and $Ca_3(PO_4)_2$ treatment. A decontamination factor of 100,000 was obtained for a 3-cycle treatment process. High volume reductions were realized by filtration, whereas the volume reduction expected by settling alone was 10 to 1.

The methods for the treatment of various process wastes to remove radioactivity were reviewed by Rodger (92). Storage of high-level solid wastes was considered inevitable. Rodger *et al.* (93) gave a detailed description of the disposal operations at the Argonne National Laboratory, including evaporation, incineration, air cleaning and concrete sealing.

The disposal of liquid wastes from the Brookhaven National Laboratory (15), their control programs concerning waste disposal (35) and research studies underway on the ultimate disposal of radioactive wastes (37) were reported. The research studies involve the adsorption of radioactivity in liquid waste by various clays which are subsequently heat treated to fix the radioactivity in fused particles for storage (land or sea) or for use in industry. Results are presented on the decontamination of waste waters high in dissolved salts and at various acidities after passage through clay columns and on the elution of radioactivity from clay after heat fixation at temperatures varying from 110° to 905° C.

Evaporation as a method of concentration for storage or disposal of Hanford fission wastes and process wastes high in sodium nitrate was discussed by Hirsh (47) and by Manowitz and Hatch (72). The wastes disposal practices, problems and costs of over 1,000 users of radioisotopes were summarized by Miller *et al.* (76). Construction material suitable for the handling and storage of corrosive radioactive wastes was reviewed by Griffiths (42). Safe methods for the packaging of radioactive wastes for sea disposal were recommended and various facets of this type of disposal were discussed by the Subcommittee on Waste Disposal and Decontamination of the National Radiation Protection Committee (102). Additional information appeared on regulations for interstate shipment (4) and on sea disposal (29).

Utilization

A symposium (111) on the utilization of fission products included papers on: the specific activity of separated fission products from reactor fuels; the technical feasibility of the use of fission products, the separation of long-lived fission products, the preservation of food and pharmaceuticals and a comprehensive bibliography on fission product utilization. Young (116) prepared a bibliography consisting of 92 references on the utilization of gross fission products. Other references on fission product utilization include Brownell (16) on destruction of bacteria, molds, yeasts and viruses; Brownell *et al.* (17) on the sterilization of foods and pharmaceuticals with a 10-kilocurie gamma source; the Argonne Laboratory (7) experimentation on fission products contained in concrete crocks for food sterilization; and Aiken (2) on disposal and uses of fission products.

Watkins and Mardock (112) reported the successful use of radioactive iodine as a tracer in water-flooding operations of the petroleum industry. Truesdale (107) found radioactive rubidium to be a good tracer in determining patterns of sewage flow in sedimentation tanks and trickling filters.

Biological Effects

Nishita *et al.* (84) investigated the adsorption of water-soluble, exchangeable and non-exchangeable forms of long- and medium-lived fission products (Sr^{89}, Sr^{90}, Y^{91}, Ru^{106}, Cs^{137}, and Ce^{144}) on eight soils and two clay minerals. The kind of clay mineral and the kind of adsorbed ion influenced fixation of isotopes. The extractability of Y^{91} and of Ce^{144} followed their respective hydrolysis curves. Plant uptake from the contaminated soils was then investigated. A relatively large amount of Sr^{90} was adsorbed and translocated to plant tops. The uptake of Y^{91}, Ru^{106}, and Ce^{144} was very small, and in most cases their translocation to plant tops was insignificant.

Rediske and Selders (91) investigated the uptake of yttrium by various higher plants. Tomato exhibited the greatest uptake efficiency (leaf to root ratio of 2×10^{-3}). Little loss occurred from the massive radioactive accumulation on the roots even when the plants were changed to solutions free of yttrium.

Porter and Knauss (60)(86) used radioactive tracers to determine the quantities of an element present in *Chlorella* when the nutrient concentration of that element was varied. Elements used in these studies were P, Ca, S, Fe, Mn, Zn, Cu, Sr, Y and H.

Studies were reported (89) of the metabolism and tissue distribution in rats of Ce, Tm and Ra, in which Ce^{144}, Tm^{170}, and Ra^{228} were used in tracer concentrations. Similar studies by Jowsey *et al.* (51) were made on the deposition of Sr^{190} in rabbit bones following intravenous injection.

Radiochemical Methods

Mizzan (78) presented a rapid method for the determination of strontium activity in the presence of the relatively long-lived fission product activities. The extraneous activities, with the exception of cesium, are removed by an yttrium hydroxide scavenging. The strontium is separated from the cesium in the supernatent solution by a strontium oxalate precipitation. The oxalate precipitate is then transferred to an aluminum disc to be dried and counted for strontium activity. The results agree with those obtained by the fuming nitric acid procedure.

Morgan (79) reported preliminary investigations on the use of versene for selectively chelating calcium. Since the order of chelation of the alkaline earths is $Ca > Mg > Sr$ it would provide a means of separating radioactive strontium from the calcium in urine. With an excess of magnesium present the pH of the specimen is adjusted to 6.0 to 6.5 and allowed to flow through a column of cation-exchanger. Essentially all of the strontium and some of the magnesium is retained by the resin, but practically all of the calcium will pass through. Keenan and Suttle (54) used thenolytrifluoroacetone as a chelating agent for praseodymium. Progress was reported (85) in studies on the radiochemical determination of tracer amounts of Sr^{89} in bulky water samples, in bone, and in urine. Turk (108) developed a modified procedure for the radiochemical analysis of strontium. The results and radiochemical purity obtained for strontium samples prepared by the modified procedure were comparable to samples prepared by the conventional fuming HNO_3 procedure. The modified procedure consists of adding strontium carrier to the sample, removing three $Fe(OH)_3$ scavenging precipitates, and isolating the strontium as $SrCO_3$.

Freiling and Bunney (32) investigated an ion exchange method for the virtually complete separation of Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd and Tb from one another in 49 hr. using lactic acid eluants of various strength at pH 3 and 87° C. Keller, Steinberg and Glendenin (55) described a radiochemical investigation of the fission

yields of 15 products in the fission of U^{235}. The fission yield *vs.* mass curve of U^{235} was compared with those of other fissile nuclei.

Hahn and Backer (43) investigated methods for the separation and radiometric determination of Cs^{134} in fission products. Cesium was precipitated with dipicrylamine and with periodic acid, using Cs or K as carrier. Turk (109) separated radioiodine from other mixed fission product except ruthenium by volatilization. Ruthenium was removed from the iodine by serial extraction with CCl_4. The precision of the method for I_2 based on ten samples is $\pm$ 2.6 per cent.

Kleinberg *et al.* (58) assembled many of the radiochemical procedures in current use for the separation of mixed fission products and heavy nucleides. The document is not readily obtainable, but a comprehensive synopsis of it appears in *Chemical Abstracts*. Lindenbaum *et al.* (70) reported on the analysis of mixtures of radioisotopes as phosphates by ion-exchange chromatography and Whitson and Kwasnoski (114) used an electrodeposition method for the determination of uranium alpha activity in urine. Krumholz and Emmons (61) and Cember, Watson and Grucci (20) described wet digestion techniques which have proved satisfactory for the routine preparation of fish and animal tissues for the determination of gross beta radioactivity.

Instrumentation

Seliger and Schwebel (95) of the National Bureau of Standards used 4-pi internal gas flow counters with or without anticoincidence counting for the primary standardization and 2-pi ionization chambers with formamide counting for the secondary standardization of beta-emitting nucleides. Various facets of standardization are discussed in detail and a comparison of results on the same samples by many laboratories was made.

Mize and Zaffarano (77) designed and tested the spectrometer for the study of soft beta rays. Beta-ray sources were deposited on thin plastic films and mounted inside the counting chamber in a detection geometry of essentially 4-pi steradians for measuring the absolute intensities of radioactive sources. Nader, Hagee, Setter and Goldin (83)(97) evaluated the performance of an internal proportional counter and, because of its good geometry and sensitivity to low-level, low-energy radiation, selected it for assaying the alpha and beta activity of water and industrial wastes. Prohaska (87)(88) found the windowless flow and the end-window counters of the Savannah River Project to have excellent operating characteristics and good reproducibility of results. Wheler, Reynolds and Brookbank (113) recommend the use of standard stock solutions of Th^{204} as a reference standard to be used in determining the over-all efficiency of the radioactivity assay of water samples by various techniques of sample preparation and counting.

Muller (81) made a systematic study of the back-scattering of 2.0-Mev betas from Y^{90} by samples of infinite thickness for 32 elements ($Z = 4$ to 83) and 22 compounds. It was established that the relative back-scattering is a discontinuous function of Z, but strictly linear in Z within each period of the periodic system. The linear equations, relating back-scattering to Z within each period, when solved simultaneously, indicate discontinuities at $Z =$ 10, 18, 36 and 54, corresponding to the rare gases which terminate the periods. The back-scattering from compounds may be accurately predicted from the scattering of their constituent atoms.

Scintillation counters for the measurement of alpha, beta and gamma activity have gained prominence during the year. The subject is covered in Curran's book (25) and in a series of seven articles and four reports appearing in the March 1954 issue of *Nucleonics*. Among the latter, Swank (103) considered recent advances,

Linden (69) presented information on new photo-multipliers and Harrison, Cowan and Reines (44) reported on large-volume liquid scintillators. Baskin (10), Belcher (11)(12), Davison *et al.* (26), Ittner and Ter-Pogossian (50), Kahn and Lyon (52), Spear (99) and Williams (115) also reported on the design and use of scintillation counters for the measurement of specific types of radiation or for spectrometry.

One of the most interesting developments is the use of solvents with liquid scintillators. For example, Terentiuk (104) improved a liquid scintillation counter for beta-ray measurements in which large amounts of solid material (up to 50 grams) were immersed in the liquid phosphor counting cell. With an anti-coincidence discriminator to eliminate high-energy cosmic radiation the measurable specific activity in a 30-min. counting period was found to be 10 $\mu\mu$c. per g. for high-energy and 100 $\mu\mu$c. per g. for low-energy beta particles. Improved end-window counting for low-level, low-energy beta emitters by anticoincidence counting was suggested by Crathorn (24) and the applicability of windowless and end-window counters and survey meters for assaying gross activity in water was reviewed by an AWWA committee (3).

LeVine (67) described an inexpensive radiation detector useful for disaster purposes where residual gamma radiation is present. The instrument indicates less than 1 roentgen/hr., from 1 to 10 roentgen/hr., and above 10 roentgen/hr. by no lights, one light and two lights, respectively. The battery-powered unit could be left on continuously, since the current drain is negligible at low radiation levels.

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Sewage Works

OXYGEN ABSORPTION STUDIES USING MECHANICAL AIR DISPERSERS *

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The efficiency of oxygen absorption in sewage and industrial wastes treatment by the activated sludge process is an important criterion in connection with proper design and sizing of equipment for carrying out this treatment process. In the Federation's manual entitled "Air Diffusion in Sewage Works" (7), the various types of air diffusers that have been used in sewage treatment are discussed in considerable detail. Particular attention is given in this manual to the use of various types of porous diffusers, although some mention is made of mechanical aerators. The mechanical aerators that are described in the manual are those which entrain atmospheric air into the mixed liquor of an activated sludge treatment plant by various schemes of surface agitation or entrainment by aspiration obtained by pumping of the mixed liquor.

The most widely used method of getting dissolved oxygen into activated sludge is that of dispersing the air into fine bubbles by passing it through various porous media. Because of various clogging problems and limitations due to excessive pressure drops, the oxygen absorption efficiency that can be obtained by dispersing air through porous media is fairly limited. The absorption efficiency is directly influenced by the interfacial surface provided, which, of course, is dependent on the size of the air bubbles for any given air flow, and the agitation and mixing that is present. The latter is important because the rate of oxygen diffusion across the air-water interface depends on the concentration of oxygen in the liquid layer of the interface, and as this absorbed oxygen in the liquid interface is removed more oxygen can be transferred into the liquid. In other words, intense agitation diffuses the absorbed oxygen throughout the entire mass of the liquid and thus keeps the concentration of oxygen at a low value in the liquid interface, thereby increasing the rate of absorption.

Kountz and Villforth (1) presented data comparing the rate of oxygen absorption of various types of aeration devices. The tests were made by measuring the rate of oxygen absorption in a solution of sodium sulfite. Their conclusions were that all the various porous types of diffuser media commonly used in sewage aeration have about the same oxygen absorption efficiency. Tests also were made on an ejector-type aerator and on an aerator which uses the so-called "impingement jet." Aeration devices of the latter type do have higher efficiency of absorption than ordinary porous diffusers; however, the total power consumed in dispersing a given amount of air is higher in these devices than for porous media. In general, the conclusion of the authors was

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that the theoretical horsepower per gram of oxygen dissolved per minute is essentially the same for all devices tested.

It has been generally accepted that the limitation on solids concentration in the aeration basins of activated sludge plants is determined by the amount of oxygen that can be dissolved in order to maintain at least 1 p.p.m. of dissolved oxygen. If the solids concentration becomes too high it is impossible for ordinary porous diffusers to supply enough oxygen to keep the proper D.O. When treating strong industrial organic wastes it is quite desirable to maintain high suspended solids in the aeration basins so as to increase the rate of oxidation. It can be concluded, therefore, that unless means are found to increase the rate of oxygen absorption, it will not be possible to reduce the size of the aeration basins below those used in the past, and also it becomes difficult to treat high-strength organic wastes by use of the activated sludge process.

This paper describes studies made on the use of various mechanical air dispersers in order to increase the rate at which oxygen can be absorbed by liquids where the rate of oxygen utilization is extremely high. It was found that by using specially designed mechanical dispersers which are fed with compressed air, it was possible to get extremely high rates of oxygen absorption. There is described in this paper the design of such a mechanical air desperser, and data are presented indicating the air dispersion capacity of such devices and the oxygen absorption efficiency that can be expected for various operating conditions.

Aeration Devices Used in Chemical Process Industry

In order to devise equipment for obtaining high oxygen absorption rates, a study was made of the aeration equipment used in several chemical process industries where high aeration rates are required to carry on the process efficiently. One of the important chemical processes where aeration equipment is used extensively is in connection with aerobic fermentation in the production of pure chemicals, antibiotics, and various food or feed substances, such as yeasts. The aerobic fermenters used for such processes have aeration-agitation equipment consisting of a high-speed turbine-type impeller, and an air sparger which supplies air to the impeller under sufficient pressure to overcome the hydrostatic head. Some of this equipment is so designed that the air is self-induced due to the negative head produced by the high-speed impeller, the air being sucked down through a hollow shaft and then dispersed by the rotating blades of the impeller. However, the usual type of equipment has the air supplied to it under pressure, since self-induced aeration requires high-speed impellers and the amount of air that can be sucked in is somewhat limited. Normally, in order to get extremely high aeration capacities the air is supplied under pressure to the impeller.

Quantitative data to permit the rational design of such mechanical gas-liquid contactors are not very extensive. The first paper on this subject in the chemical engineering literature was presented in 1944 by Cooper, Fernstrom, and Miller (2). They rationalized that the rate of solution of a gas in a liquid was a function of the area of gas-liquid interface, the temperature, the time of contact, the magnitude of the driving force, and the intensity of agitation. The area of contact, time of contact, and agitation are the variables which can be controlled by the design of the gas-liquid contacting equipment. A mechanical gas disperser breaks up the air bubbles and disperses them throughout the liquid. The breaking up of the bubbles is accomplished by the shearing action of the high-speed rotating

blades of the impeller moving through the liquid. In accomplishing this breaking up of the bubbles considerable agitation and turbulence is produced. Such turbulence and agitation are important in increasing the rate of gas absorption. The previously mentioned writers conducted tests on small models of gas dispersers, using a copper-catalyzed sulfite-water solution for absorbing the oxygen. Since then it has become a standard procedure in studying the relative efficiencies of various gas-liquid contactors to use this type of oxygen absorption system, because it can be easily controlled and reproducible data are obtained.

Foust, Mack, and Rushton (3) made quantitative observations on the ability of various types of mixers to disperse gases in liquids in various size tanks by measuring the amount of air held up or retained in bubble form in a tank. They presented the concept of hold-up or retention and contact time. The actual retention or hold-up of gas in the liquid was obtained by accurate measurement of the volume of liquid in the tank before and during aeration. The difference between the two volumes represents the volume of air entrained or held up. They theorized that the average contact time between the gas and the liquid could be calculated by dividing the hold-up by the air flow.

During the last few years there has been an extensive amount of literature in chemical engineering journals relating to the transfer of oxygen in submerged aerobic fermentation processes. Hixson and Gaden (4) state that fundamentally the problem is to transport oxygen from the air to the respiratory enzyme system of the cells at a rate sufficiently high that metabolic activity will not be limited by the availability of oxygen. This, basically, describes what it is desired to accomplish in the aeration basins of activated sludge treatment processes. Both Hixon and Gaden (4) and Bartholomew, Karow, and Sfat (5) have presented some of the basic fundamentals of oxygen transfer in aerobic biological systems. Eckenfelder (6) has used the basic ideas presented by the foregoing investigators in indicating how their concepts can be applied in a practical way to the design of aeration equipment for carrying out the activated sludge treatment process. There is no question that the work carried on by the various experimenters studying the basic phenomena of oxygen transfer in submerged fermentation have presented ideas and concepts which if properly applied to the activated sludge treatment process will go a long way toward eliminating much of the empiricism that exists in connection with the application of the process to sewage and industrial wastes.

In studying oxygen transfer efficiencies and uptake rates the investigators of fermentation processes made the following three assumptions, which apply equally well in connection with the activated sludge process: First, it is assumed that maximum respiration is desirable. Secondly, only the oxygen dissolved in the liquid is available to the cells for respiration. There has been some evidence that direct transfer of oxygen from gas bubbles to cells is possible; however, such transfer is probably of negligible importance. Third, it is implied that the respiratory metabolism will constitute the only oxygen demand of the system. It is possible, of course, for oxygen to be used up by nonenzymatic oxidation by certain compounds in the liquid substrate. With these assumptions an oxygen absorption coefficient can be derived and measured experimentally. Such a diffusion coefficient will depend, as indicated previously, on the area of gas-liquid interface, the time of contact, and the agitation intensity. These three factors will be controlled by the aeration rate; the bubble size, which, of course, is deter-

mined by the type of air dispersion device; the agitator speed and design; and the physical properties of the liquid, such as viscosity, density, and surface tension.

No further detailed discussion of the theory developed by the experimenters on submerged fermentation is presented here. The author simply wishes to emphasize that the sanitary engineering profession can benefit greatly by drawing on the research and developments made in the fermentation industry, both in connection with the basic theory of oxygen absorption and also in regard to equipment used for high-rate oxygen transfer.

Design of Mechanical Disperser and Model Tests

In designing a mechanical air disperser suitable for use in the activated sludge process when treating sewage and various industrial wastes, consideration was given to all the factors of design established by the experimenters working in the field of submerged aerobic fermentation. In addition, it was kept in mind that any such mechanical disperser must be so constructed that fairly large solids and such material as strings, rags, and other matter that might be present in the screened sewage must not clog or hinder the operation of the disperser.

Several designs were studied on a model scale. In addition, various schemes for supplying the compressed air to the disperser were investigated, and also such items as location of the disperser relative to the bottom of the basin and the influence of various geometric configurations of the disperser and the blades. It was finally established that there was relatively little difference in oxygen absorption efficiency between elaborately constructed impellers with curved vanes as compared with impellers having relatively simple radial vanes. The final design of impeller was that

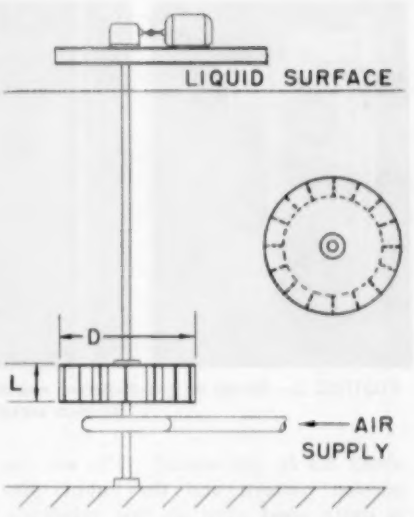

FIGURE 1.—General design of mechanical gas disperser.

shown in Figure 1. It is relatively simple to build, can be made quite strong structurally, and can be made quite easily from various corrosion resistant materials if desired, or coated for corrosion and abrasion prevention.

A sparger ring immediately below the inlet to the impeller serves the purpose of distributing the incoming air uniformly to the inner periphery of the radial blades. A powerful centrifugal pumping action is produced by the impeller and the air is entrained by the entering liquid. As it passes through the blades of the impeller and is discharged radially, the air bubbles are subjected to a powerful shearing action. The number of radial blades is never less than 12 and may be as high as 24 for larger impellers. The height of the blades is normally kept between one-third and one-fourth of the impeller diameter. The radial length of the blades is approximately one-sixth of the impeller diameter. In Figure 2 is shown a 6-in. diameter impeller in a 30-in. diameter tank dispersing air while revolving at a speed such that the peripheral velocity is

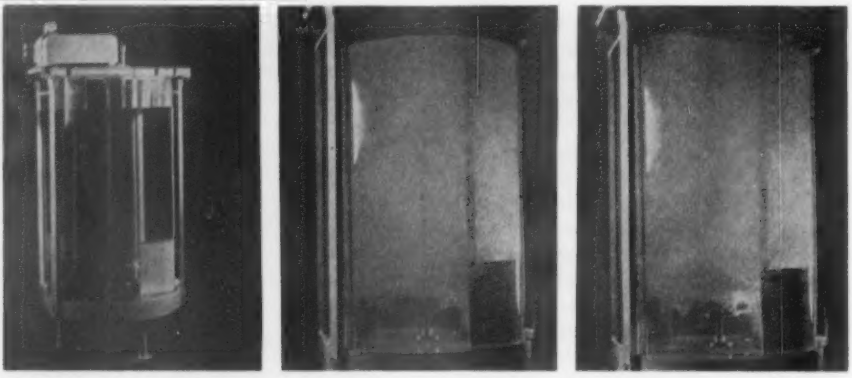

FIGURE 2.—Model of gas disperser not in use (left), at low aeration rate (center), and at high aeration rate (right).

about 8.5 ft. per second. The air dispersion pattern and the bubble size is quite good even at this relatively low peripheral velocity. The installation of properly located baffles is quite important to prevent a swirling motion of the water, which tends to make the bubble pattern quite non-uniform and greatly decreases the outward dispersion of the bubbles from the rotor.

Model Test Data

Once the general design of the impeller was selected, an extensive series of tests was made on various small-size impellers in order to establish such important design criteria as oxygen absorption efficiency as related to peripheral velocity and air flow, and power consumption. Several geometrically similar impellers were constructed varying in diameter from 3 in. to 12 in.

Using the copper-catalyzed sodium sulfite solution technique, oxygen absorption efficiency data were obtained from various sizes of the impellers, operated at various peripheral velocities, and dispersing different amounts of air. From principles of dimensional analysis and the hydraulic model laws, the data obtained were correlated and generalized. The data (Figure 3) indicate that the oxygen absorption efficiency for this design of impellers increases as the 3/2 power of the peripheral velocity and varies inversely as the square root of the factor S, which is the rate of air flow through the impeller expressed in c.f.s. per unit peripheral area. Using the symbols shown in Figure 1, the peripheral area can be expressed as πDL. It should be noted from Figure 3 that absorption efficiencies as high as 38 per cent were obtained. Peripheral velocities of the various size rotors varied from about 5 ft. to about 25 ft. per second.

The other important factor that was determined in these model tests was the power consumed by the impeller for various peripheral speeds and aeration rates. Using dimensional analyses, the data obtained were generalized (Figure 4). The power required varied directly as the peripheral area of the rotor and as the cube of the peripheral velocity. This is to be expected, since basically this impeller should have the general hydraulic behavior of a centrifugal pump. The power decreased as the amount of air per unit peripheral area increased. In other words, as the liquid flowing through the impeller became lighter in density due to the entrained air, the power consumption fell off. By the use of the curve or the empirical equation shown in Fig-

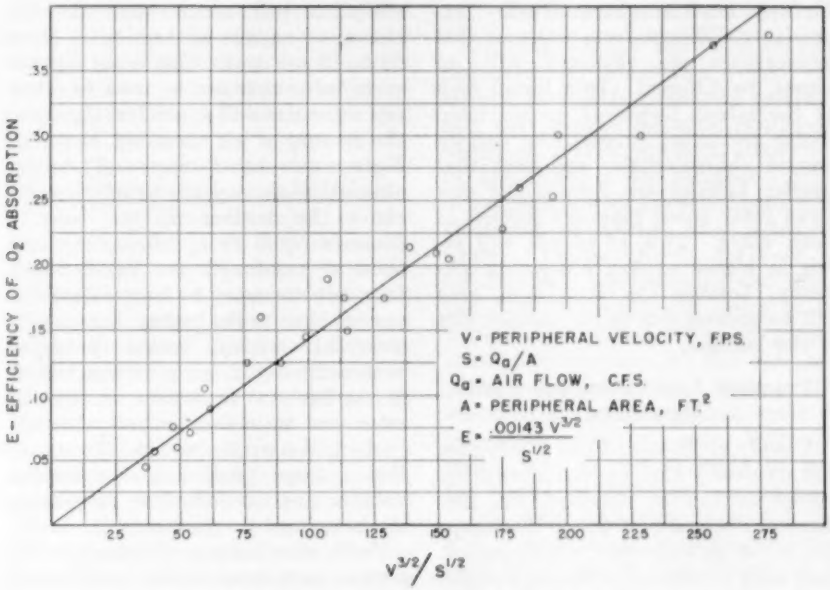

FIGURE 3.—Oxygen absorption efficiency.

ure 4 it is possible to calculate the power required for any size of impeller when dispersing any given quantity of air.

It should, of course, be kept in mind that these model tests were made with a water-like liquid. Power consumption will unquestionably be greater if the density or viscosity of the liquid is appreciably greater than that of water. The oxygen absorption efficiency data shown in Figure 3 are for water at a temperature of about 70° F. For any other liquid which has

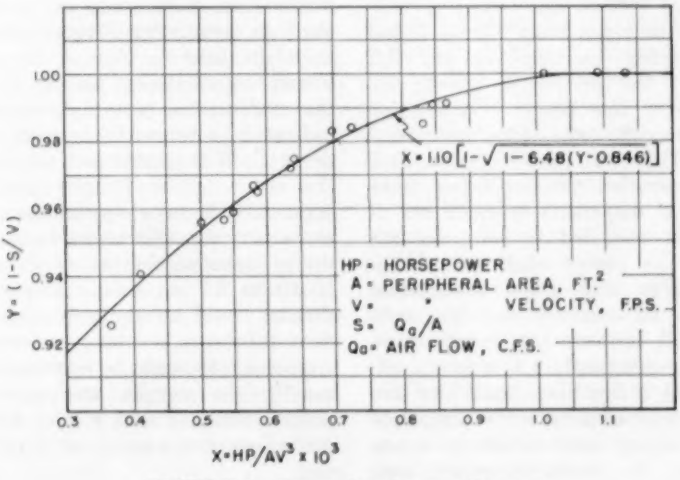

FIGURE 4.—Power data for gas disperser.

surface tension characteristics appreciably different from water at that temperature the efficiency will, of course, be different. In a liquid such as the mixed liquor of an activated sludge treatment process, the surface tension characteristics are such that smaller bubbles are formed for any given rotor speed than are formed in clean water. This, of course, will result in higher oxygen absorption efficiency, because the interfacial area will be greater due to the smaller size of the bubbles.

Practical Application and Field Verification

A study of Figures 3 and 4 indicates that unusually high oxygen absorption efficiencies can be obtained wih mechanical dispersers if power consumption is not an important consideration. Such high absorption efficiencies might be desirable in chemical process work where operating costs are secondary to first cost of equipment. With such high absorption efficiencies a fermenter could, of course, be made much smaller than if lower efficiencies were employed. However, in sewage treatment, and even in industrial waste treatment, operating cost cannot be ignored. Therefore, high absorption efficiencies become uneconomical.

It will be noted from Figure 3 that the efficiency increases as the 3/2 power of the peripheral speed; unfortunately, the power consumption increases as the cube of the peripheral speed. The total power consumption in any aeration process using these mechanical dispersers is made up of the power required to compress the air and the power used by the impeller. For any given installation condition an analysis can be made which will indicate the point where the power consumption is a minimum. In general, it has been found that for the depths of submergence of impellers used in sewage and industrial waste treatment, the minimum power consumption will occur when the efficiency of oxygen absorption is about 10 to 12 per cent. This is an approximate value that can be used in selecting rotor size and speed for dispersing the amount of air necessary to supply a given amount of oxygen. These mechanical dispersers are usually located above the bottom of the basin a distance equal to approximately one-third or one-fourth the liquid depth. It is not necessary to locate these dispersers close to the bottom, because the powerful mixing action produced causes the liquid lying on the bottom of the basin to be drawn up into the rotor and intimately mixed with air. In fact, the mixing action is so strong that a large portion of the smaller bubbles are carried down almost to the bottom of the basin.

Field installations of these air dispersers have been made in activated sludge treatment plants for domestic sewage, wood pulp washing wastes, refinery waste for phenol removal, and vegetable and fruit canning wastes. Impellers have been designed and installed having diameters up to 6 ft. and dispersing air up to 2,000 c.f.m. per impeller. Good verification has been obtained in regard to the power consumption, since power measurements have been made on several of the field installations. Some data have been obtained in regard to oxygen absorption efficiency, and in all cases the efficiency has been higher than that indicated by the model test data (Figure 4). With peripheral velocities of the order of 10 ft. per second, it apparently is quite easy to obtain oxygen absorption efficiencies in activated sludge aeration basins of the order of 10 to 12 per cent. Higher efficiencies could be easily obtained, but the total power consumption would be increased. It might be mentioned that usually the oxygen absorption efficiencies obtained with porous diffusion media are of the order of 5 to 7 per cent.

In the case of the treatment of the wood pulp washing waste, which had a high concentration of wood sugars and tannins, calculations indicated that absorption efficiencies of the order of 15 to 20 per cent were obtained; however, under those conditions severe frothing occurred, because of the low surface tension of the liquor, with the result that extremely fine bubbles were formed. In other words, in such a case even though high efficiencies were readily obtained at normal impeller speeds the froth formation made it impossible to operate at such high absorption efficiency. Another limitation in connection with attempts to maintain high rotor speeds and high absorption efficiencies in activated sludge treatment plants is that such operating conditions result in extremely fine bubble formation, and there is a tendency for such fine bubbles to remain attached to the activated sludge floc, with the result that such floc does not settle well and may even float. In other words, if one does not worry about power consumption, high oxygen absorption efficiencies theoretically can be obtained in an activated sludge treatment process by the use of mechanical air dispersers; however, conditions may be created which will make the floc difficult to separate from the liquid. In other words, high impeller speeds for maintaining high efficiencies may create undesirable conditions, such as air entrainment and flotation of floc, excessive frothing or colloidizing of the solids.

In conclusion, it might be mentioned that mechanical air dispersers such as described herein would afford the only practical means for efficiently utilizing pure oxygen for aerobic treatment of wastes if and when such oxygen should become available and can be economically used for such purposes. Only with such mechanical dispersers could pure oxygen be efficiently utilized.

Conclusions and Summary

Utilizing some of the basic concepts employed in connection with submerged aerobic fermentation processes and the agitation-aeration equipment employed in such processes, a mechanical air disperser was designed for use in connection with the activated sludge treatment of sewage and industrial wastes. Design criteria for such an air disperser are presented and model test data relating to the sizing of the impeller, peripheral velocities, oxygen absorption efficiency, air flow rate, and power consumed are given. The model data were generalized using dimensional analyses and hydraulic model laws so that it could be used for designing full-scale equipment.

The data presented indicated that such a mechanical gas-disperser when used for dispersing compressed air in an activated sludge aeration basin could produce oxygen absorption efficiencies on the order of 30 to 40 per cent. However, such high absorption efficiencies would require very high power consumptions, and the cost of absorbing a given quantity of oxygen under such operating conditions would be appreciably greater than absorbing the same quantity of oxygen under operating conditions where the efficiency of absorption would be lower. Although such high efficiencies might be justified in industrial processes, it is extremely doubtful whether such high efficiency of oxygen absorption could be justified for sewage and industrial waste treatment. In general, it was established that an oxygen absorption efficiency of the order of 10 to 12 per cent would be the most economical operating point as far as total power consumption is concerned. From the data presented the size of the impeller and the power required can be determined for any given rate of oxygen absorption that it is necessary to provide at the desired absorption efficiency.

Such mechanical air dispersers, because of their ability to produce higher oxygen absorption rates, permit the use of higher solids concentration in the mixed liquor of activated sludge plants, and also make it practical to treat high-strength industrial organic wastes by the activated sludge process.

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DISCUSSION

By H. R. KING

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Mr. Kalinske has described a recently developed mechanical aerator, in which the major part of the oxygen absorption takes place from small air bubbles. The bubbles are produced by injecting compressed air into liquid entering the inlet of an impeller at the bottom of a circular aeration tank. The rotating blades break the air up and disperse it in the form of small bubbles in the liquid discharging from the impeller. Circulation of the contents of the tank occurs due to the lifting effect of the air bubbles and the pumping action of the impeller.

This type of aerator is similar to diffused-air aeration in regard to the oxygen absorption process involved. The impeller replaces the air diffuser as a means of producing small air bubbles. The author reports that very high rates of oxygen absorption were obtained from the aerator in model tests performed with copper-catalyzed sodium sulfite solution. Using dimensional analyses, data from the tests pertaining to the operation of the impeller have been generalized and are plotted on diagrams. A study of the data by the writer indicates that the power consumption of the impeller is probably high in relation to the oxygen absorption accomplished.

Mr. Kalinske apparently believes there is a great need for this type of aerator in the activated sludge process due to his impression that diffused air aeration has limitations as to oxygen absorption rates obtainable because of the clogging and power losses involved in the operation of porous diffusers. The writer, however, is of the opinion that a careful study of air diffusion would reveal that porous diffusers do not comply with the objections as cited.

Therefore, it is of interest to note that the power cost which can be rightfully charged to porous diffusers in the activated sludge process is normally only a relatively small part of the total required for air compression. For example, the pressure losses in porous plate diffusers amount to only

2 to 8 per cent of the total pressure required at the blowers in three large activated sludge plants in The Sanitary District of Chicago, in which sewage is treated in 15-ft. deep aeration tanks at an average rate of about 1,100 m.g.d. In one of these plants, porous plate diffusers operating on very clean air have shown no appreciable increase in losses since their installation about five years ago. In fact, clean air has practically stopped the clogging of porous diffusers at this particular plant. General recognition of the value of exceptionally clean air should result in much less clogging of porous diffusers in the future and should also lead to improvement in the efficiency of oxygen absorption by means of air diffusion.

It should also be noted that the power chargeable to porous diffusers, as related to the total power required for air compression, should not be any greater at high rates of oxygen absorption than at low rates. In the design of an air diffusion system the rate of air application should be taken into consideration and the number of diffusers and sizes of piping selected for installation should, in general, be in proportion to the air requirements. Therefore, for a properly designed air diffusion system, the pressure losses due to diffusers and piping should be about the same for a system to be operated at a high rate of air application as for one to be operated at a low rate of air application.

High rates of oxygen absorption can be obtained by means of diffused air aeration. This has been indicated by tests in The Sanitary District of Chicago on model tanks using sodium sulfite solution. Formulas have been derived from the tests relating the rate of oxygen absorption to such factors as rate of air application, oxygen deficiency, temperature, depth, and bubble size. For example, in a 15-ft. deep spiral flow aeration tank with air diffusing in ⅛-in. bubbles from a porous plate diffuser area equal to 10 per cent of the tank area, the formulas indicate that an oxygen absorption rate of 100 p.p.m. per hour, or the equivalent of 150 lb. per day per 1,000 cu. ft. of liquid, could be obtained in sulfite solution at an air rate of 42 c.f.m. per 1,000 cu. ft. of tank liquid volume. In the activated sludge process, however, due to a lower absorption efficiency, as indicated by tests, the air rate would have to be about 70 c.f.m., which, allowing for blower efficiency and pressure losses, would mean about 0.35 kw-hr. of power per pound of oxygen absorbed. For the rate of air application that would be needed for activated sludge a diffuser plate area of 20 to 25 per cent would be required to reduce the air rate per plate to a reasonable amount and this would, also, reduce the air required to some extent. The rate of oxygen absorption that would obtain would be from 4 to 6 times that required in aeration tanks in the Sanitary District. Thus, with proper design very high rates of oxygen absorption can be obtained by means of porous diffusers.

As a result of this experimental work the writer does not agree with the author that "the limitation on solids concentration in aeration basins of activated sludge plants is determined by the amount of oxygen that can be dissolved in order to maintain dissolved oxygen of at least 1 p.p.m." and that "if the solids concentration becomes too high it becomes impossible for ordinary porous diffusers to supply enough oxygen to keep the proper D.O." This may be true in some particular plants. It does not, however, hold true if air diffuser systems are properly designed to meet the oxygen absorption requirements.

In fact, it is not the rate at which oxygen can be dissolved that usually limits the solids concentrations in aeration basins. Other factors generally determine the extent to which aeration tank volume can be reduced

by increasing the solids concentration and retaining the same amount of solids under aeration. For instance, in the conventional activated sludge process there is the economical limitation due to the cost of providing the additional final settling tanks necessary to increase the rate of solids return to the aeration tanks. In addition, there is the physical limitation to which activated sludge can be concentrated in the sludge return. Also, there is an economical limitation due to the increased power requirements per unit of oxygen absorption as the required rate of absorption is increased by reducing the aeration tanks volume. This limitation in regard to power was indicated by tests in the Sanitary District of Chicago on spiral flow aeration tanks. Power required per pound of oxygen entering solution increased with the rate of oxygen absorption raised to a power of 0.3 and lower depending on the depth and the porous plate diffuser area in relation to the tank area.

Because of such controlling factors as the foregoing and others pertaining to the operation of the activated sludge process, there is, no doubt, an optimum relationship between the aeration and final tank volumes which will result in the most economical plant for treating a particular sewage. But, it is quite probable that the knowledge acquired in regard to the process since its discovery has resulted in many plants that operate with very favorable ratios of aeration and final tank volumes. For that reason, it is doubtful if there will be any great increases in the rates of oxygen absorption in the process from those as generally required at the present time.

There are, however, industrial wastes which require high rates of oxygen absorption for treatment; also industrial processes having high oxygen demands. The aerator described by the author may be suitable under such conditions, particularly if it can be established that a mixing action of great intensity is necessary. Diffused air can also produce high rates of oxygen absorption. The value of an aerator of the type described by the author depends on how it compares with diffused-air aeration and other types of mechanical aerators on a power basis, taking into consideration other factors such as fixed charges in the plants involved and the costs for maintenance and labor in operating the equipment.

This type of mechanical aerator uses compressed air. Therefore, for test purposes, it would be comparatively simple to replace the impeller with a porous diffuser. Then by measuring power requirements at various oxygen absorption rates first with the impeller and then with the porous diffuser operating, relative data could be obtained pertaining to the rates of oxygen absorption obtainable and the power requirements per pound of oxygen put into solution at various absorption rates. Data of this kind would be informative and would reduce to a considerable extent the necessity for speculation as to the relative merits of the two methods of aeration.

DISCUSSION

By A. A. Kalinske

Mr. King's discussion implies that the writer was attempting to criticize diffused-air type of aeration, and was offering an aeration method that should be used in place of diffused-air aeration schemes. This was not the purpose of the writer's paper, and he is sorry that such a misinterpretation

has been placed on its contents. The writer was simply describing a different method of aeration, which in some instances offers advantages over diffused air, and which may have broader application for aeration of activated sludge for the treatment of various types of industrial wastes. Dispersing air by means of porous diffusers, in order to obtain required oxygen absorption, is undoubtedly the most practical and most economical scheme of aeration for many activated sludge treatment plants. With all the facts in hand, any engineer can make an analysis comparing first cost and operating cost for any aeration scheme. Certainly any particular aeration method should not be used unless economical and technical analyses indicate that it is the best for that particular problem. The principal purpose of the writer's paper was to present some technical information that would permit making such analyses in connection with a mechanical air disperser.

Mr. King states that this type of mechanical aerator is similar to diffused-air aeration in regard to the oxygen absorption process involved. This is not quite correct, since with the mechanical air disperser there is the dual action of formation of fine bubbles and mechanical stirring. The stirring action is independent of the amount of bubble formation, which, of course, is not true in diffused air aeration. Buswell (8) and Mohlman and Wheeler (9) have clearly pointed out the importance of stirring in obtaining good oxygen absorption in the mixed liquor of activated sludge treatment plants. The combination of diffused air and mechanical stirring has been discussed in the technical literature quite frequently, and has been used in some plants in Europe.

Mr. King takes strong exception to the writer's remarks that porous diffusers are sometimes plagued with clogging problems. Considering the large number of articles in the technical press dealing with clogging and cleaning of porous diffusers, it would appear that the writer is justified in making his observation. For instance, in the Federation's manual on air diffusion (7) a statement is made that reported practice indicates that the frequency of cleaning diffusers varies from about one month to more than 20 years. In other words, clogging of porous diffusers is an extremely variable item, and the mere fact that clogging seems to have been minimized at the Sanitary District of Chicago treatment plants, does not mean that such problems are not present elsewhere. Much has been accomplished in the last several years to reduce clogging problems, but it would be far from the truth to indicate that clogging of porous diffusers is no longer a serious problem in activated sludge treatment plants. Nevertheless, the writer does believe that porous diffusers are undoubtedly the most economical means of dispersing air in many activated sludge treatment plants, particularly where the sewage or waste being treated is not too strong.

Mr. King states that high rates of oxygen absorption can be obtained by means of diffused air aeration. It is not clear what is meant by "high rates." Mr. King cites some data obtained on tests with model tanks using porous plate diffusers and a sulfite solution for absorbing oxygen, and indicates that an oxygen absorption efficiency of about 15 per cent was obtained. The writer indicated in his paper that with mechanical dispersers practically any absorption efficiency desired can be obtained, and gave data showing that absorption efficiencies approaching 40 per cent are readily attainable. Mr. King cites some data where the oxygen absorption rate was 100 p.p.m. per hour, which is equivalent to 150 lb. per day per 1,000 cu. ft. of liquid, and this was obtained in a

sulfite solution at an air rate of 42 c.f.m. in the 1,000 cu. ft. of tank liquid volume. Using a similar experimental technique, an oxygen absorption rate of 360 p.p.m. per hour was obtained with a mechanical air disperser such as described in the paper. This was accomplished in a tank such that the rate of oxygen absorption per 1,000 cu. ft. of liquid was 500 lb. per day. The total power consumption, which includes the power used for compressing the air and the power used to drive the disperser, was 0.40 kw.-hr. per pound of oxygen absorbed. This particular experiment was carried on in a tank having a total liquid depth of 30 in. With properly designed mechanical dispersers, liquid depth is not a very important factor as far as oxygen absorption is concerned because of the intense mechanical mixing. Such shallow liquid depth with porous diffusers would, of course, result in very poor oxygen absorption efficiency.

Mr. King indicates that the absorption efficiency is substantially less in the activated sludge liquor than in the sulfite solution. This is undoubtedly true for porous diffusers, but experimental data do not indicate that this holds true for mechanical air dispersers. The reason for this is that in the activated sludge mixed liquor the increased viscosity of the liquid makes it more difficult to obtain proper mixing and contacting with the air bubbles when mechanical agitation is absent. This has been clearly demonstrated, for example, in the aeration of very thick suspensions, such as are present in yeast fermenters. Metcalf and Eddy (10), in reporting some tests at Milwaukee, Wis., stated that: "Where sludge containing 2 to 3 per cent of solids was aerated, the air appeared to accumulate in large bubbles and escape from the surface at irregular intervals. This tendency appeared to render the air less effective as a means of agitation and possibly to interfere to some extent with the uniform distribution of dissolved oxygen throughout the sludge."

Mohlman (11) has made similar observations and has stated, for instance, that it is doubtful whether dissolved oxygen can be present in the concentrated sludge present in re-aeration tanks. There appears to be sufficiently conclusive evidence that the writer's statement is valid regarding the fact that the solids concentration in activated sludge mixed liquor will undoubtedly be controlled by the ability to get sufficient oxygen into the thicker slurry. Of course, this limitation probably is of no great significance for sludge concentrations appreciably below 5,000 p.p.m., but it certainly is of all-important significance for higher sludge concentrations. Such high sludge concentrations must many times be used for treating strong industrial wastes if the aeration tank capacity is to be kept within economic limits. Of course, as Mr. King points out, there may be other factors which must be considered in connection with the limitation on solids concentration, but the ability to supply a sufficient amount of oxygen is certainly one of the more important factors that must be kept in mind. For instance, Gehm (12) says that a sludge having 10,000 p.p.m. of solids could remove 400 lb. of B.O.D. per 1,000 cu. ft. of aeration capacity at a 90 per cent removal efficiency. However, he states that ordinary porous diffusers could not be used for aerating such a sludge, and that some type of mechanical disperser such as used in commercial fermenters would be necessary.

There is evidence that higher solids concentration in the mixed liquor of activated sludge tends to reduce frothing troubles, and many operators have in recent years tried to keep the solids concentration higher than is necessary as far as treatment is concerned in order to reduce frothing. Of course, keeping the solids concentration higher than necessary is not economi-

cal operation as far as air consumption is concerned, but if it reduces frothing problems such extra expenditure for power may be justified. The only limitation on the solids concentration in that case is the settling characteristics of the activated sludge, and the ability to get oxygen into such thick slurries.

Mr. King states that there is an increased power requirement per unit of oxygen absorption as the required rate of absorption is increased by reducing aeration tank volume. This is unquestionably true with diffused-air aeration, and is also true beyond a certain limit of rate of oxygen absorption when using mechanical aerators such as described by the writer. As pointed out by the writer in his discussion of the test data, the oxygen absorption efficiency tends to increase with the speed of the impeller; however, the power consumption of the rotor tends to increase also, and at a more rapid rate than the absorption efficiency, and therefore, a point is reached where the total power consumption (for example, power for compressing air and power to the impeller) increases at such a rate that more power is required for each pound of oxygen absorbed than would be required at lower speeds and lower efficiencies. Of course, such higher operating cost may be justified and overbalanced by the lower capital investment in reduced aeration tank volume.

The writer did not present any specific field data where mechanical air dispersers of the design described have been used, and because of the questions raised by Mr. King, perhaps some such data should be cited: First, the writer would like to mention some data obtained with carborundum porous diffusers when tested in the same tank (about 30-in. water depth) as were the mechanical air dispersers. As noted in the paper, oxygen absorption efficiencies varying from a few per cent up to almost 40 per cent were obtained with mechanical dispersers. With porous diffusers, having a permeability of about 35, under similar test conditions, the maximum efficiency that it was possible to obtain never exceeded 6 per cent. These tests were all made using sodium sulfite as the oxygen absorber. Mr. King mentioned his test data with porous diffusers and indicates that oxygen uptake rates of the order of 100 p.p.m. per hour were obtained. With mechanical air dispersers uptake rates of 300 p.p.m. and greater can readily be obtained, and such uptake rates are necessary for certain industrial wastes treatment, such as were indicated by Eckenfelder (6). In a plant handling a vegetable and fruit canning waste, an aeration tank having a volume of 5,500 cu. ft. was equipped with several mechanical air dispersers, such as described in the paper. The total air supplied was 830 c.f.m. and measurements indicated a total oxygen absorption of 160 lb. per hour, which gives an absorption efficiency of about 13 per cent. This rate of oxygen absorption is equivalent to 520 lb. per day per 1,000 cu. ft. of aeration tank capacity. In the same aeration basin, oxygen absorption efficiencies as high as 33 per cent were obtained when the total air supplied was of the order of 200 c.f.m. The total power consumption, including that to the compressors and to the mechanical dispersers, was 0.235 kw.-hr. per pound of oxygen absorbed.

In treatment units for handling strong domestic sewage, B.O.D. removals of as high as 400 lb. per day per 1,000 cu. ft. of aeration capacity were obtained in treating units equipped with the mechanical gas dispersers described in the paper. In one series of tests, 300 lb. of B.O.D. were removed per day per 1,000 cu. ft. of aeration capacity with a total air consumption of 300 cu. ft. per pound of B.O.D. removed. Stanley (13), in his study of various activated

sludge treatment plants using diffused air, has indicated that B.O.D. removal per 24 hr. per 1,000 cu. ft. of aeration capacity varied from 15 to 50 lb., and the air required per pound of B.O.D. removal ranged from 500 to 1,600 cu. ft. Activated sludge treatment units for domestic sewage are now being designed, using such mechanical aeration equipment, on the basis of 300 lb. of B.O.D. removal per 24 hr. per 1,000 cu. ft. of aeration volume, at a removal efficiency of 90 per cent or more. Sufficient field data have been accumulated to permit such design figures to be used safely.

It is hoped that the foregoing comments and the citation of data will help to answer some of the questions raised by Mr. King, and permit proper interpretation of the material presented in the paper.

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WHAT IS A SANITARY ENGINEER?

On December 14, 1954, the Committee on Sanitary Engineering and Environment, Division of Medical Sciences, National Academy of Sciences—National Research Council, approved the following definition of the term "Sanitary Engineer":

"The practice of sanitary engineering includes the following activities:

"1. Surveys, reports, designs, reviews, direction, management, operation and investigation of works or programs for:

(a) Water supply, treatment, and distribution.
(b) The collection, treatment, and disposal of community wastes; *viz.*, sanitary sewage, industrial wastes, and refuse, including salvage and reclamation of useful components of such wastes.
(c) The control of pollution of surface waterways and ground waters, and of surface and subsurface soils.
(d) Milk and food sanitation.
(e) Housing and institutional sanitation.
(f) Insect and vermin control or eradication.
(g) Rural, camp, and recreation place sanitation.
(h) The control of atmospheric pollution and air quality, and of light, noise, vibration, and toxic materials, including application to work spaces in industrial establishments (industrial hygiene engineering).
(i) The prevention of radiation exposure.
(j) Other fields that have as their major objective the control of environmental factors affecting health.

"2. Professional research and development work supporting the activities listed in 1.

"3. Responsible teaching of sanitary engineering subjects in educational institutions of recognized standing."

Industrial Wastes

1954 INDUSTRIAL WASTES FORUM *

KENNETH S. WATSON, *Leader*

Coordinator of Waste Treatment, General Electric Realty Corp., Schenectady, N. Y.

Chairman Watson:—In this forum it is proposed to deal with some of the fundamental considerations in the handling of industrial wastes. Because the initial consideration in the handling of industrial wastes perhaps is the matter of their approved disposal, the bulk of this discussion will be concerned with this facet of the subject.

The disposal of industrial wastes for most practical purposes means their discharge by one of two alternate methods: passing them into a municipal sewer system either with or without pretreatment, or conducting them to the nearest stream either without or after treatment.

Even though this subject is supposed to be simple, the more one thinks about it and works on it, the more complicated it becomes and the more facets it seems to have.

The discharge of industrial waste into a municipal sewer system means that the industry in question must be accountable to the city, to protect the sewer system and the sewage treatment plant. The provisions of the permit from the city to the industry, or the provisions of an agreement which might exist or be negotiated between the city and industry, fall within the general framework of the municipal ordinance which is in effect in that city.

In connection with the discharge into a municipal system, there are two particular points to be considered with reference to the industrial waste ordinance. First, should industrial waste concentrations be listed in a municipal ordinance in general terms, or should they be spelled out in detail? The second point for consideration is should industrial waste specifications apply to the individual plant effluents, or should they apply to the composite effluent at the sewage treatment plant?

The final topic for consideration is: Where an industry has a choice, what is the soundest approach—discharge into the municipal sewer system, or into the stream?

Of the six discussion leaders, one considers the affirmative viewpoint, another the negative, of each of the particular points mentioned. In fairness to the panel it is pointed out that the views expressed by any member do not necessarily represent those of all members of the panel. The point should, perhaps, also be made that the views expressed are personal and do not necessarily represent those of the organization with which the discussor is associated.

Industrial Waste Specifications in Municipal Ordinances

Fenton H. Dobb, Senior Engineer, Sewage Disposal Section, City of Cincinnati, Ohio:—In the past 75 to 100 years billions of dollars have been lit-

* From transcript, 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; October 11–14, 1954.

erally buried beneath the ground in the form of vast systems of sewers and waste carrying conduits, which provide a cleaner, healthier environment. The term "buried" is used because it seems to express adequately the attitude of the layman taxpayer who, after demanding and financing a costly sewer system, promptly forgets its existence as soon as the connections are made and the trenches are backfilled and leveled. The old adage "out of sight, out of mind," seems to fit the situation perfectly.

As a result of this attitude, sewage collection systems are probably the most misused and abused of all public facilities. The taxpayer demands proper use and maintenance of publicly owned facilities (such as buildings and roads) which are built on the ground surface, but ignores the sewer which is buried and out of sight. Thus arises the general misconception that sewers will carry away any unwanted wastes, regardless of physical of chemical characteristics, with no damage to the conduit.

To protect the investment of its citizens, every political subdivision served by a sewer system, regardless of its size, should adopt a complete, suitable, and workable ordinance for the control and regulation of the uses of the system and for the protection of existing and proposed sewage treatment works.

The drafting of such an ordinance should be a cooperative endeavor, with adequate representation of all interested and involved factions. Municipal officials, representatives of industry, consulting engineers, and legal talent, all properly qualified, should be brought together to contribute their professional knowledge and experience to the formation of the ordinance. The result should be a workable legislation wrapping up in a single package the machinery for regulation and control of the system and tailored to the requirements of the community and the wastes being contributed. Waste contributors to a typical sewer system can be classified roughly into two specific groups, as follows:

1. The domestic contributors. This group is composed of occupants of private homes, operators of hotels, restaurants, and other businesses who rarely discharge wastes of greater strengths than "normal." However, through ignorance or carelessness, this group occasionally discharges small quantities of deleterious substances.

2. The industrial and commercial contributors. Large quantities of wastes of greatly varying characteristics and high strengths from a large variety of industrial processes are discharged by plants and factories in the average industrial community. These wastes, unless regulated and controlled by legislation, can be responsible for untold damages to sewer systems and can reduce the efficiency or even incapacitate sewage treatment works. The expense of expanding existing treatment works to adequately treat uncontrolled industrial waste loads places an additional tax burden on the citizens of the community.

Special limiting specifications in an ordinance are therefore directed primarily toward the regulation of industrial wastes. Since these wastes vary so widely in volume, constituents and concentrations, the limitations should be spelled out, either directly in the ordinance or in the rules and regulations authorized by the ordinance. Advantages of defining specifications and limitations in the ordinance can be listed as follows:

1. Simplification of administration. If each industry had to be considered individually with regard to allowable or chargeable concentrations of waste constituents, as would be necessary if specifications were not clearly defined, the administration and field work in-

volved would be cumbersome and costly.

2. Equity amongst industry. With specifications clearly spelled out, there is no basis for one industry to believe another is being favored or no opportunity for a municipality to favor one industry over another. Standards are set down which must be conformed with regardless of size or type of industry.

3. What industry can expect. All industry, including new companies coming into the city, will know exactly what concentrations of wastes are objectionable and can take action to comply with the regulations.

4. Equity of charge. All companies subjected to sewer charges based on strengths of wastes which are spelled out in an ordinance are assured that each company is bearing its share of the load with no favoritism being shown.

5. Enabling industry to plan ahead. In most cases, the expense to industry created by the ordinance cannot be recovered. Clearly spelling out in the ordinance the limitations and bases of charge will enable industries to adjust their budgets and methods of production to absorb these expenditures in the most favorable fashion.

To define each limitation of waste strengths and constituent concentrations directly in an ordinance alone would, in most cases, result in an unwieldy and inflexible legislation. To provide flexibility, the ordinance should authorize a set of rules and regulations in which limitations and bases of charge are spelled out. These could be amended to fit the program as it progresses, without the necessity of time-consuming council action or the enactment of new legislation.

In conclusion, it has been the experience of the City of Cincinnati that its service charge and industrial wastes ordinances and rules and regulations, which were drafted with the cooperation of industry and other interested parties and in which the limits of waste strength concentrations and bases of service charge and surcharge are clearly defined, have all resulted in a workable program in which citizens and industry are striving toward a common end—that of cleaner and healthier living.

A. J. Steffen, Sanitary Engineer, Wilson & Co., Chicago, Ill.:—Waste treatment and disposal is a part of production and industry's interest does not end when the waste enters the floor drain. In other words, industry recognizes fully its responsibility to the agencies handling its liquid wastes. Industrial sanitary engineers are continually developing new ways to prevent and utilize wastes which might become problems when discharged into the sewer.

There are at present more than 20 active committees in industry, organized specifically for the promotion of waste treatment and waste prevention and for conducting research and developing information in this field. A tremendous volume of information is disseminated by these groups through pamphlets, talks and motion pictures. Since most of this material is aimed at people in the industries involved, little knowledge of these activities filters through to sewage treatment plant operators and sanitary engineers not in industry. This is unfortunate, but steps to correct the situation are being taken by the National Technical Task Committee organized by the United States Public Health Service. It is hoped that through this agency more of this information will become available to workers in the sewage treatment field.

Just as industry recognizes its responsibilities to sewage treatment agencies, so too, the sewage treatment works manager will recognize his responsibilities to help promote healthy industrial development and encourage normal community growth by guard-

ing against unnecessary restrictions for industrial waste discharges.

Here are some questions which should be answered before any industrial waste clause is written into a sewer ordinance:

1. Is the waste in question a safety hazard when dumped into the sewers? If so, it should, without question, be eliminated from the sewers.

2. Is the public health affected by the discharge of this waste into the sewers? Can the public health be affected by conditions resulting from efforts on the part of the industry involved to comply with the proposed restrictions? For example, a real public health hazard may develop from collecting and hauling a waste which might be handled in the city sewers without damage.

3. What does it cost the sewer authority to handle the problem of extra labor, extra equipment, or—in the case of accelerated wear or corrosion—, in replacement of sewers or equipment at increased frequency? Perhaps the clogging of the sewer in question can be prevented by semi-annual cleaning instead of annual cleaning. This would represent an extra cost. Perhaps a different type of jointing material in a short length of local sewer will prevent damage from corrosive wastes.

4. What will it cost industry to conform to the proposed restrictions? Will a holding tank do the job? Will hauling and dumping be necessary? What will it cost per year? Each waste should be handled at the lowest ultimate cost, no matter which agency actually performs the operation.

5. How much of the waste, in concentration and in volume, can be tolerated in the sewers from the existing industries? Is the restriction going to work an undue hardship on any existing industry, just to protect the sewers or treatment plant against industries yet unborn? Restrictions should be based on actual existing conditions, not on theoretical extreme conditions that may never happen and that in the end can be prevented by the simple expedient of a permit system for new sewer connections.

Maximum quantities or concentrations of deleterious materials should not be spelled out in an ordinance. Such restrictions can cause unintended hardship for an industry that may discharge insignificant quantities of the waste in question into a relatively large sewer flow. For example, a bottling plant may be prevented from discharging caustic from a bottle washer if a maximum pH is spelled out, even though the volume of this waste may be insignificant.

What would a realistic industrial waste section of a sewer ordinance look like? First, the discharge of explosive gases; liquids, solids or semi-solids capable of clogging the sewers; corrosive materials capable of damage to the sewers; or toxic, poisonous or noxious materials, should be prohibited. Questions of temperature limits, grease and solids concentrations, and similar characteristics can be covered by a statement as follows: "No waste shall be discharged, without pretreatment, into the sewers which, because of temperature, solids concentrations, grease content or other characteristics, will cause, either directly or indirectly, special difficulties or extra expense in the maintenance and operation of the sewers and sewage treatment works unless special contractual arrangements are made with the industry to defray the cost involved."

This type of industrial waste clause is sufficiently restrictive to prevent abuses and is still broad enough to avoid unrealistic limitations which may ultimately restrict the normal industrial growth of the community.

Where sewer service charges are based on volume, surcharges for B.O.D. concentration over and above

a set limit are sometimes prescribed, as pointed out by the previous speaker. In all cases, however, any problems encountered in handling industrial effluents should be solved by a committee of technical people representing the city and industry. This committee would be familiar with the limitations of the public sewer system and the treatment plant and the characteristics of the industries and their effluents. This committee can determine whether pretreatment is necessary and, if so, to what degree; it can determine whether treatment at the municipal sewage treatment plant is more economical; and it can determine the limits within which the industry must operate its waste control program.

I do not agree with all the restrictions in the model sewer ordinance which appears in the Federation's Manual of Practice No. 3,* but I do agree with the guiding principle stated on page 7 of the manual: "A soundly conceived sewer ordinance is beneficial to industry as well as to the municipality, for it makes possible maximum use of the public facilities for all wastes that can be handled effectively."

Don E. Bloodgood, Professor of Sanitary Engineering, Purdue University, Lafayette, Ind.:—As a member of the committee that worked on M.O.P. No. 3, I would like to point out that a great deal of effort was spent in trying to establish in the model ordinance what were believed to be sound limits. At that time it seemed reasonable to establish some kind of ordinance based on the experience recorded in the literature, rather than completely on the ideas of the committee. Mr. Steffen may be right, however, because some of the ordinances adopted since publication of the manual, and one in particular, have no limit on grease.

Mr. Steffen advocates a committee of industry and city government management to establish wastes concentration limits. That is a fine idea, but implementation of the decisions of such a committee would present grave practical problems.

Mr. Steffen:—The limitations, as previously mentioned, can best be determined for each individual case, preferably by a committee of technical people, and the organization and the power of a technical committee of that type should be spelled out in the sewer ordinance.

Adequate grease recovery at the local plant is, again, something that the technical committee can determine as needed in each individual case. There are good, efficient grease recovery facilities available to industry, so there should be no question about that. However, as to whether limits should be included in the ordinance, that is something else again. There may be some small operator, even a restaurant let's say, that perhaps has a conventional grease recovery system but discharges more than the 100 p.p.m. specified in the ordinance. If the discharge is to a large sewer, that contributor may not be creating a problem that would require action by the municipality, requiring him, perhaps, to build an expensive and elaborate grease recovery system.

Dean M. Taylor, USPHS, Cincinnati, Ohio:—I'd like to ask Mr. Dobb to expand a point be brought up in regard to the placing of most of these definitions. Should these limits be outlined in the rules and regulations rather than in the ordinance itself? Also, can flexibility and change be made appropriately? If a system of charges as set up proves to be inadequate, what can be done to develop that program to meet the situation?

Mr. Dobb:—In the formation of an ordinance there should be some defi-

* "Municipal Sewer Ordinances." Man. of Pract. No. 3, Federation of Sewage and Industrial Wastes Assns., Champaign, Ill. (1949).

nite provision for periodic review of the ordinance, the rules and regulations, the prohibitions, etc. If the concentrations and strengths gathered by experience can be lowered or raised, if the charges are too great, or if operation expenses go up or down, in the course of review each should be raised or lowered to fit the existing conditions.

H. H. Black, USPHS, Cincinnati, Ohio:—Someone has used the expression "damages could result from uncontrolled discharge." I'd prefer to have it put in the positive sense and find out how to get positive control of the uncontrolled discharge, whether it be to a sewage treatment plant or a stream.

Mr. Dobb:—In speaking strictly from the point of view of the City of Cincinnati—and it can be applied to all municipalities, large or small—the point of control lies with the authority created by the ordinance. Cincinnati is working out a point of control, although that goal has not been fully realized as yet.

Through primary, secondary and tertiary questionnaires directed to industry, and returned by them in a very cooperative spirit, the industrial effluent strengths have been determined. The city also has developed a gaging and sampling program for checking the effluent from industry, and through the cooperation of industry—by their own gaging and sampling and spot-check by the City of Cincinnati in its gaging and sampling program—a very good control has been established and a positive knowledge of the industrial wastes of this city has been gained.

N. S. Bubbis, General Manager, Greater Winnipeg Sanitary District, Winnipeg, Man.: It is not desirable, nor does it always work out in practice, to deal with each industrial wastes case specifically. In Winnipeg, for example, nine packing plants had to be dealt with. Dealing with them individually did not get us very far; but when they realized that a definite standard was going to apply to all of them, large and small, we got results. It is necessary to have a definite standard for a given industry, so that all plants of that industry are dealt with in the same manner and are placed on more or less competitive basis.

Our legal counsel had considerable to do with the drafting of the industrial waste ordinance of the Greater Winnipeg Sanitary District. Perhaps that is why it was arranged and phrased as it is. We certainly feel that it is a realistic approach to the problem and we have proven that it can be applied in practice. The ordinance starts with all the prohibitions; it states that this particular substance or certain substances over certain strengths shall not be discharged to the sewers. After listing the exclusions it goes on to state that notwithstanding specific exclusions, wastes of concentrations greater than those specified may be discharged by special license. That provision was included to take care of those small industries or small plants that discharge negligible quantities of high-strength waste which in the total result does not create problems to either the collection system or the treatment plant.

It is necessary to include in the ordinance a provision which enables the municipal authority to insist that industry provide a sampling and/or measuring manhole so located that it is accessible at all times. In making prosecution it must be established in the courts that the particular waste being objected to actually came from the particular industry being prosecuted. If that can't be done, the charges cannot be pressed home.

Mr. Steffen:—That escape clause is a handy device, but it does weaken whatever effort was made to require a limitation. It also brings out the thought that perhaps it might be just as well not to have that limitation,

and let the limitation be spelled out by a committee made up of technical people. However, it is possible to see the advantages of an arrangement of that character. It certainly does permit the small user of the sewers, who normally is not causing any damage, to exceed the limitation that the ordinance spells out.

I don't think any industrial representative would want to use the sewers to the damage of the public or use the sewers beyond the limits for which he is paying. Generally he wants to pay for what he is getting, and it is not intended to indicate in any way that industry wants a free ride. However, it is not fair to penalize one industry for the misfortune of another. If an industry is large enough, and has the type of waste that causes a problem in the municipal sewers or the municipal sewage treatment plant, whereas another one is lucky enough to be small and doesn't cause that problem, I don't see why the small one should be penalized along with the large one.

In the same instance, if one is discharging into a large sewer flow where the dilution effect is such that a corrosive element in the waste would not create difficulties, and another is discharging perhaps the same amount into a small sewer, but is causing corrosion because of the relative proportion of sewage flow against the discharge, the latter, of course, will have to pay for the condition. But why penalize the first plant because of the misfortune of the other for having selected a place on a sewer where such trouble arises?

H. Heukelekian, Research Specialist, N. J. Agricultural Experiment Station, New Brunswick, N. J.:—There are some general guiding principles that are pertinent to this discussion. First, any industrial waste should be accepted into the sewers unless actual damage can be shown. Then, when prohibitions are to be placed, they should not be placed on the basis of concentration of specific constituents in the effluent, but on the concentration in the sewer. In other words, the dilution factor should be taken into account.

There are too many existing ordinances which sound more or less arbitrary in the light of the present state of knowledge. They are too detailed to be enforced, even though they are on the books as valid statues; therefore, they are just never enforced. Why not reduce prohibitions and concentration limits to the minimum necessary, and then actually enforce them?

Mr. Dobb:—Actually, to enforce an ordinance, particularly one with many rules, regulations, and prohibitions and where the burden of proof is on the city, requires a staff larger than most cities can consider.

Suppose harmful concentrations of deleterious materials arrive at the sewage treatment plant in a fairly large municipality. How does one trace the origin of those materials? In a city with 800 or 900 mi. of sewers, a complete survey of the whole sewer system would be required unless the investigators are lucky enough to find that contributor within the first few miles. Such a process is time consuming and expensive.

Chairman Watson:—The discussion has begun to touch on the second phase of this subject. Therefore, it seems appropriate to present it and discuss both the first and second phases together.

Waste Specifications—Applied at Source or at Treatment Plant?

F. B. Milligan, Sanitary Engineer, Pennsylvania Department of Health, Harrisburg, Pa.:—There are a number of good reasons why industrial waste specifications should apply to the discharge as it leaves the mill or factory where it is produced, rather than to the general mixture of sanitary sew-

age from the town and industrial wastes from assorted industries as this combined flow enters the municipal treatment plant. Before discussing these reasons, a few remarks seem to be in order.

It should be recognized that the requirements necessary for an existing municipal sewage treatment plant are pretty rigidly dictated by the type of plant and its capacity as to the volume, nature and concentration of the influent which it can handle successfully. No matter what the surcharge or rental which the townspeople or the industrial establishments concerned might be willing to pay, certain physical limits hold, beyond which no more industrial waste or sewage can be received.

A new plant, on the other hand, can be designed to handle any combination of sewage and industrial wastes which is treatable in the present state of the art. In most cases the best solution for a given degree of treatment will be that which is the most economical in the long run for all concerned.

For any municipality, the decision as to how large a new or enlarged municipal plant is to be, and of what type, should be made only after a careful study, preferably by an experienced engineer who can evaluate the many factors which always must be considered, and make sound recommendations.

A great deal depends, of course, on the size of the town as compared with the industrial load—that is, on the amount of dilution which can be expected, as well as on the degree of flow-equalization, neutralization of acid by alkaline wastes, and similar factors.

In most cases, municipal ordinances should impose maximum limits for suspended solids and B.O.D. in industrial wastes, beyond which these characteristics should be subject to surcharges. It is essential that a sound basis be established for such surcharges, perhaps on population equivalents; one for the B.O.D., another for suspended solids, another for volume.

There can be little question that certain requirements, at least, should apply to all industrial wastes (and sanitary sewage as well) as they leave the industrial establishment which produces them, if they are to be admitted to the municipal sewers and treatment works. Some substances must usually be excluded from the municipal system except in very small amounts. These include the following:

1. Volatile oils such as gasoline, tar, and other wastes produced by garages, oil refineries, and chemical industries, and causing fire and explosion hazards and disturbance at sewage treatment works.

2. Acid wastes from metal pickling and oil refineries; also caustic wastes, such as kier liquor from textile mills or rag digester wastes from paper mills. Wastes of these types damage sewer structures and equipment, and interfere with biological treatment processes.

3. Highly toxic substances, especially cyanides or compounds of selenium, chromium, etc., from metallurgical and other industrial processes, phenols from gas works, arsenic and lead from chemical and other plants. These wastes endanger human life, disrupt biological sewage treatment, and must be collected and disposed of safely without discharge, or must be treated for practically complete removal of poisonous qualities before discharge either to sewers or streams unless they are negligible in amount.

Wastes with other objectionable characteristics also must be excluded or pretreated before admission to the municipal sewer system. These may be grouped about as follows:

1. Excessive inorganic solids, including coal ash, foundry sand, sawdust, and straw.

2. Suspended solids such as brewery and distillery mash, fibers and solids from abattoirs, leather tanneries, vegetable canneries, and wool scouring. (Spent grain, blood and paunch manure can be collected and sold.)

3. Suspended solids found in paper mill wastes, whole slop from breweries and distilleries, screened wastes from vegetable canneries, etc. (Paper mill wastes are generally excluded from sewer systems.)

4. In addition, neither extremely hot water nor excessive volumes of any kind of waste should be tolerated in the sewer system.

Objectionable substances or characteristics in industrial wastes often can be considerably reduced by good housekeeping or modified plant processes or both. If this is not enough, pretreatment usually improves a waste sufficiently for admission to the public sewers.

Each municipality should establish ordinances with specifications setting maximum limits for the salient characteristics of industrial wastes ordinarily encountered, with equitable surcharges (for example, for B.O.D. and suspended solids loadings beyond the established limits), which should be determined on the basis of the relative volume and nature of the sewage and the various types of industrial wastes at present existing or anticipated during the expected life of the municipal plant, and on the size of that plant and its treatment capacity.

These specifications should be applied at the point of origin of the wastes—that is, at the point of discharge from the establishment producing the wastes—for such reasons as the following:

1. The only way in which the municipal requirements can be entirely equitable as between the load placed on the municipal treatment plant by the domestic sewage from the town, and that placed by any given industry, or between one industry and another, is to require that all wastes and sewage meet standard specifications requiring elimination of toxic, explosive, and other harmful characteristics, and fixing proper surcharge rates for types of wastes which are treatable but would impose an additional load on the plant.

The total surcharge for each mill or factory should be the sum of surcharges for the waste volume and for each kind of pollution load. Charges could be computed on the basis of sewage population equivalents for volume, B.O.D. and suspended solids. If the wastes also contain grease, iron, etc., charges for these would have to be determined differently.

2. It is only possible to determine equitable service charges if all industries in a municipality must do comparable jobs of pretreating or conditioning their wastes before discharge.

3. Without standard specifications or requirements for all industrial effluents, difficulties caused at a sewage treatment plant by industrial wastes would entail a tremendous amount of work to determine the establishment whose wastes were responsible and the amount of pretreatment necesary to correct such difficulties.

If municipal ordinances are written to apply to the industrial effluent at the factory, then it would be feasible to require a regular program of effluent sampling and analysis at each factory, with occasional checks by the city. This would provide a solid basis for service charges, would make management aware of its industrial waste problem, and would provide data on the effectiveness of any pretreatment required.

It is certainly true that limiting values must be placed on the volume and characteristics of the influent to

a municipal treatment plant at the plant. These will be dictated by its size and type (and, therefore, its treating capacity).

The problem is to establish specifications which, when they are applied to the factory effluent at the factory, will produce an acceptable influent to the municipal treatment plant. These specifications could be determined by the following procedure. Suppose that the municipality has adopted a limiting requirement of 5 p.p.m. iron in the incoming combined wastes to the municipal treatment works. The total volume of combined wastes must be measured or estimated in any case. Then, the number of pounds of iron which may be received per day into the treatment works can be determined, and this amount can be prorated among existing industries, with a suitable allowance for anticipated future requirements. Then, knowing the volume of discharge from a given industrial establishment, the amount of iron which its wastes may carry without exceeding the allowable amount at the municipal treatment works can be determined, in p.p.m. if desired. Similarly, all other waste specifications can be determined or allocated for each industrial plant served by a given treatment works.

Volume and waste characteristics must be determined by a survey of the town and of each industrial discharge, followed by suitable contracts between the municipality and the waste-producing establishments. The ordinance then could contain a requirement that the wastes from any factory may not exceed in daily volume the amount specified in the contract for the admission of these wastes into the municipal system.

Fred C. Olds, Plant Engineer, Procter & Gamble, Cincinnati, Ohio: —The fundamental objective of a waste disposal project is to get the required job done at the least over-all cost to the community, the community being composed of individual homes, business establishments and industries. The philosophy behind the project should be that of creating a favorable waste disposal climate which will attract new industry to the area.

The City has many responsibilities in the matter of waste disposal. Three of these bear directly on the question under discussion.

First, it is necessary for the city to determine the size and nature of the plant required, based on the existing wastes in the sewers at the time of a survey. Then, of course, there must be due allowance for an anticipated growth in the area. Second, when this is done, the city in some way has to provide revenue for the construction and operation of the plant. Third, when the plant is constructed, the city has to protect the sewers, and protect the operation of its plant.

These things bring up the necessity for industrial waste specifications, which do three things: First, they provide surcharge revenue; second, they protect the sewers; and third, they protect the operation of the plant.

Of all these specifications, only two need apply at the source. The first of these is one specification which sets up the definition of a normal sewage in terms of, say, B.O.D. and suspended solids, and provides for the payment of a surcharge where the effluent from the industry exceeds this definition of normal.

The second specification is one which protects the sewers. This excludes the harmful materials mentioned by Mr. Milligan, and they are selected for obvious reasons. This, again, is a single specification.

The two specifications just mentioned are the only two that need apply at the source.

The rest of the industrial waste specifications are written for the purpose of insuring that the treatment plant can operate satisfactorily on the influent which it receives; therefore,

it seems logical that these specifications should apply to the influent at the plant. Provision can be made to restrict at the source when some concentration exceeds its specified limit at the waste plant.

If all this group of specifications applied at the source, the dilution factor would be ignored. For instance, there might occur in the sewer at an industry concentrations of oils, or metals, which at the same strength would give trouble in the treatment plant. However, these may very shortly be reduced to harmless concentrations by the larger volumes of diluting sewage in the intercepting sewer.

More specifically in this connection, the specification at the source can severely penalize a small contributor of concentrated sewage who actually is adding only a minute increment to the strength of the influent as it arrives at the plant, whereas a large contributor of a somewhat smaller and acceptable concentration is, perhaps, creating a much more severe problem.

Finally, the city has geared its service and surcharges to the strength and volume of the contribution of each industry. The industry, therefore, pays its fair share of the cost of construction and operation of the plant. Once it has eliminated the objectionable materials from the sewer, it has a right to expect the city to accept its effluent up to a point where the loading is such that the influent at the treatment plant exceeds the maximum allowable concentration of some specified material and begins to cause difficulty at the plant.

Chairman Watson:—In discussions between industry and municipalities, it quite often is possible that the two groups may be talking about different specifications. For example, the industry may be talking about specifications at the sewage treatment plant and the municipality may be talking about specifications at the industrial effluent. Sometimes an understanding of the basis for mutual agreement is slow in coming. In having dealt with a number of cities on that subject, I think sanitary engineering and professional industrial waste people need to give a lot of clear thought to trying to arrive at a pattern which makes sense.

Arthur D. Caster, Sewage Disposal Engineer, City of Cincinnati, Ohio:—Messrs. Steffen and Olds both brought out the point that they are trying to set up stream standards for the sizing of sewers. I think municipal sewers are entirely different from streams, and if industry is to be asked to remove certain prohibited substances sewer discharges, the requirement must be city-wide.

Any charges that municipalities place upon industries are part of the industries' production costs. If there are two industries of the same type side by side, but with one discharging into a small sewer and one into a large sewer, and there are different standards for the two types of sewers, the industry on the large sewer gets a benefit and, other things being equal, has lower production costs than the plant on the small sewer.

Mr. Olds:—In that connection, the city should have the attitude that the size of its sewers and the size of its treatment plant are not sacred, and should be expanded or enlarged as required. This is but another factor in creating a favorable atmosphere for the waste disposal situation in the area.

Mr. Steffen:—My comment on this question of relative dilution related only to what possible damage there might be to the sewer in question.

Of course, if a waste causes a problem at the treatment plant, it should be charged for, but if the sewer in question is not harmed, it is not fair to charge the small industry just because the large industry is causing the problem that requires a special

charge. It isn't fair to ask one industry to throw money away just because another industry has the misfortune of being improperly—or let's say unfortunately—located.

William S. Wise, Director, Connecticut State Water Commission, Hartford, Conn.:—Three questions are prompted by this discussion; first, suppose conditions in the sewage system of a municipality are entirely satisfactory as far as the discharge of industrial wastes into the system is concerned during 1954. However, a new industrial concern locates on the system in 1955 and discharges a substantial volume of toxic industrial wastes similar in character to those now discharged by some of the existing industries. Should the new industry be required to bear the whole burden of pre-treatment or should the city go to the existing industries and ask them to bear a portion of the cost of reducing the combined concentration down to the accepted limits?

The second question deals with determination of concentrations of toxic industrial wastes. Are the samples used for the determination collected over a 24-hr. composite period or are they collected over shorter periods of time? During boom times many industries operate around the clock and the concentration of toxic substances during the low night sewage flows would be much greater than during the high day sewage flows. The reverse would also be true in cases where industries operated only during an 8-hr. period. In this case the concentration during the night flows would be zero, whereas it might be quite heavy during the day.

The third question concerns cyanide concentrations and pH. If the concentrations of these substances are determined only at the treatment plant it may be found that they are entirely within safe limits. However, an industry may be located on one of the branch sewers and may be discharging substantial volumes of cyanide-bearing wastes into a sewer into which a substantial amount of acid wastes had been discharged. Under such conditions the discharge of these wastes would prove to be a great hazard, not only to the sewer system itself, but also to the personnel engaged in the maintenance of the sewer system because of the possible evolution of hydrocyanic acid gas. Would it not be well to set concentration standards for the discharges into the sewer system from industrial plants?

Mr. Steffen:—The first question sounds like a stream standards question; whether the new user should have to bear the full brunt of the situation he is causing when existing users have been getting along in pretty good shape. That goes back to stream philosophy, too, where perhaps one party is using the capacity of the stream for self recovery and then another user comes along and upsets the apple cart. Which one pays the bill? Wiser heads than mine have tried to answer that one.

A situation of that character should be answered, however, by the committee previously suggested, the committee being empowered by legislation to take whatever action is necessary. Leaving it up to a committee takes away the onus of a requirement by an individual.

The model ordinance suggests that the requirements be set up by the superintendent of the sewage treatment plant. That is too much of a burden to ask one man to shoulder. Where a new industry comes in and causes a problem, after existing industries of the same type and discharging the same type of wastes have been getting along with the existing treatment plant, the committee should determine an equitable solution.

As regards the question of sampling, composites should be taken over the normal operating period of the industry, which is not necessarily a

24-hr. period. Although an industry may operate 24 hr., the actual load of processing may run 8 or 10 hr., the remainder perhaps being clean-up, cooling water, etc. Therefore, the day should be broken up into sections, depending on the operating characteristics of the particular industry.

As regards the question of cyanide, certainly any hazardous, damaging, toxic or noxious materials should be prohibited from entering the sewers.

Mr. Olds:—The question of who bears the cost when a new industry comes in has been rather neatly handled by the new Cincinnati ordinance. Under this ordinance existing industries are paying service charges and surcharges, which are going towards the amortization of plant facilities not yet built. The plant is being built, however, in anticipation of future growth, so existing industries are building capacity for industries and householders not yet located in the area. Some time in the future, the capacity of that plant will be reached due to growth in the area, and a new plant must be built. Presumably on the same basis as now holds, those in the contributing area at that time will be faced with financing construction of a new plant.

The question of operating cost when a new industry comes in has likewise been resolved. The new industry will contribute materials to the sewer which will cost the city money to remove or to handle. The ordinance specifies that the city shall examine its operation and determine the cost of handling a pound of B.O.D., or a pound of suspended solids. When the new industry comes into the picture, it is charged proportionately for its contribution. In other words, it pays its way as far as the operation of the plant goes.

George Rhame, Sanitary Engineer, Division of Water Pollution Control, State Board of Health, Columbia, S. C.:—South Carolina has stream standards. But whether called stream standards or industrial waste specifications of an ordinance, the same fundamental engineering problems have to be solved. There is one big advantage, however, in municipal waste disposal: When wastes increase, another sewage treatment plant can be built, but it's impossible to put in another stream. There is no simple solution to the problem of waste disposal; it is inherently complicated.

James Crane, Cincinnati Chemical Works, Inc., Cincinnati, Ohio:—There seems to be a confusion of two problems—the policy problem and the factual problem.

Engineers and technicians, in general, follow the policy that is set down by city councils or other governing bodies. These governing bodies decide, based on engineering facts and recommendations, what the general policies will be. As an example, in Cincinnati it was decided that all citizens, both corporate and individual, will make advance contributions for sewage plants to be built large enough to take care of the industrial loads and future loads. There was quite a bit of controversy between the sewage people and the industries, but it was finally resolved by the City Council, which is as it should be. It is very necessary that the governing bodies have full technical advice before acting.

Chairman Watson:—Is the necessary experience and the know-how of technical people always properly called upon and used by the regulatory bodies in developing ordinances?

Frank Woodbury Jones, Consulting Engineer, Cleveland, Ohio:—A previous speaker has, perhaps, overstressed one point a bit. As I interpret his remarks, he implied that a city should take into its sewer system any amount and kind of waste, provided the industry paid for it. This is not always practicable. Again, one of the panel stated that if a treatment plant

became overloaded it is a simple matter to expand the works. This, also, is not as easy as it sounds.

There should be limitations on both quantity and quality of process wastes in order to avoid undue burden on a municipality or on its sewage treatment works. As a case in point, a small municipality built a sewage plant some years ago, designed to serve for about 20 years. It was a fine plant and produced an excellent effluent for two years. At that time the local Chamber of Commerce, in an endeavor to bring industry to the town, raised about $1,500, purchased a site, and presented it to the industry. The town fathers, as is often the case, gave no thought to the industrial wastes, particularly in respect to a possible hazard to results at the treatment plant. The industry referred to produces a waste of very high pollution characteristics. In fact, it contributes 20 per cent of the total flow, and 75 per cent of the total B.O.D. arriving at the plant. In other words, the industrial load is one-fifth the total in volume, and three times the organic load, contained in all of the domestic sewage.

That happened years ago, and although the plant has been seriously overloaded and under a stigma because of poor results, it is only recently that definite progress has been made toward improvement.

In general, there should be some means, not necessarily by ordinance, but preferably by agreement, so that, in the event a sudden wastes load is imposed by industry, such load could be modified to prevent an undue burden on the municipal treatment plant.

In respect to control of admissions to the sewer system, in at least one city it is specified that in no hour must the concentration of waste be more than three times the average. Control should also be imposed on wastes which interact with each other, when mixed, to create a hazard.

A large industry is inclined to the viewpoint that it should not have restrictions which are not imposed on a smaller industry with similar wastes, and this point appears well taken. Consequently, where all industries of the same type are treated alike, much better cooperation can be expected.

Oftentime one hears: "If we get such and such an imposition, we shall have to move out of town." This is fraught with difficulty too, because no matter where the industry goes, the waste problem goes along also.

In all my experience, I have never found that a city or municipal government wanted to penalize industry. By the same token, it is certainly a pleasure to find that today industry is actively cooperating in solving mutual pollution problems.

Mr. Dobb:—In Cincinnati the technical know-how got through to Council for various reasons: Consulting engineers were first called in, and then there were meetings between city and industry representatives over a period of weeks; in fact, the consultations with industry continued for more than three years. As a result, all the technical know-how that was available from the consultants who were familiar with the sewage field, and from the technicians in industry, was thoroughly and pretty well brought together. The fruits of this labor are contained in the Cincinnati ordinance.

Mr. Wise:—Sometimes it is questionable whether these problems should be solved largely on a technical level or on a management level. A series of instances in Connecticut will illustrate the point:

For several years meetings had been held with a group of similar industries in an effort to set up a program of waste treatment for the industries as a whole. These meetings were held with technical representatives from the various industries. No substantial progress for setting up a program was made because the representatives

felt that one of their duties was to keep the cost of operations down in their individual plants and that waste treatment would increase the over-all cost of plant operation. A conference was arranged with the managements of the various industries and progressive action was obtained because management gave the green light.

Mr. Jones:—It should be noted that in Cincinnati, for example, the normal sewage, above which the surcharge is made, is more than reasonably strong. In other words, 300 p.p.m. of suspended solids, and 240 p.p.m. of B.O.D. is a strong sewage that at once permits a number of small industries, and contributors of various kinds, to get in under the normal rates. It is only after that level is reached that the surcharge becomes effective. Therefore, industrial or commercial contributions, get a break of perhaps 20 to 25 per cent before even the surcharge is brought into play.

Mr. Olds:—For Procter and Gamble the surcharge exceeds the service charge by considerable, and that, we feel, is a right and equitable thing; if we are contributing that strength, we should pay our correct proportion of the charge.

William H. Higgins, Superintendent, Ewing-Lawrence Sewage Treatment Works, Trenton, N. J.:—Two widely divergent approaches by industry can be seen in our communities. One industry, originally producing a waste containing 30 p.p.m. of cyanide, has in a year's time improved its effluent until it now contains less than 1 p.p.m., and efforts are being continued to reduce it even more.

Another industry produces cooked rubber wastes which clogs the sewer system and clogs the treatment facilities. Although negotiations have been carried on for more than a year, this industry refuses to make satisfactory progress. Therefore, because that waste raises the suspended solids in the municipal plant effluent to 7,000 p.p.m., the authority will have to refuse the waste until it is pretreated.

E. S. Chase, Consulting Engineer, Boston, Mass.:—Like the poor, the industrial wastes problem is with us always. It is a topic which has been discussed at great length.

The question has been raised as to how to treat the small industry as against the big industry. I'd like to call attention to criminal law where there is a differentiation between petit larceny and grand larceny.

Another point that has been touched upon is the action of Chambers of Commerce in trying to bring new industry into small communities. In one small community with which I am familiar, the Chamber of Commerce attempted to get a wool scouring plant to move in. Fortunately, the industry had sense enough to ask for advice as to the degree of treatment which might be required before their wastes could be put into the city sewers. The city had a nice, relatively new sewage treatment plant, which would have been badly overloaded had that industry's wastes been permitted in the sewer system. Therefore, the industry decided not to locate in that particular community.

This experience indicates the responsibility of industry to investigate the problems it faces before locating in a new section of the country, or even in a new community in the same section.

Chairman Watson:—In the interest of objectivity, a member of the Forum audience has been asked to briefly summarize the two phases of this subject that have thus far been discussed—Mr. Palmer.

Clyde L. Palmer, Assistant City Engineer, Detroit, Michigan:—This whole subject was aptly summarized by the gentleman who made the statement that there are two phases to it—the policy phase and the engineering phase.

Engineers are interested in both

phases. Certainly the engineer should be on the policy making board. There are, however, things that this policy board will have to consider, that are not entirely engineering. The local conditions that have to be met in the matter of financing is an important factor in determining how the ordinance should read; whether the use of surcharges is to be resorted to as part of the financing picture, or whether the financing is such that the entire benefit of the plant can be turned over for the free use of all, two different but entirely valid viewpoints depending entirely on the viewpoint of the policy making body of the community in which the problem arises.

For the engineer however, there are some more definite limitations that will have to be met. Basically, of course, the whole problem will go back to the receiving waters. Some of the limitations that will have to be placed upon the use of the public sewer system will be the result of conditions created in the receiving waters. Other limitations will be as a result of the sewage process in use, and others as a result of using the sewer structure as a means of transportation to the point of final disposal.

Industry, or any of the users of a public sewer system and a sewage disposal system, cannot escape these limitations. It is a question only of how they are to be administered. The fact remains, however, that there are definite quality limitations imposed on sewage and industrial wastes by virtue of their effect on the receiving waters, the sewage treatment process, the equipment, and the structures of the sewer system itself.

In about the year 1945 the City of Detroit started working on its standards and regulations. Previous to that time, there were no regulations and reliance was placed on the ordinance, which said in effect that industry or any user could not discharge any deleterious material into the sewer system.

Several industries created serious damage in the sewer system. In compliance with the ordinance they paid sizable sums of money, but as usual there was the cry: "Why doesn't somebody tell us these things?" Therefore, in an attempt to keep people out of trouble, and to protect the city's interest, the standards and regulations for controlling the use of the sewers were formulated.

In the present discussions, there does not seem to be a great difference between the viewpoints of municipal agencies and industry. Industry agrees that certain substances should be entirely prohibited in the sewer system, but it contends that other things should not be limited to too great an extent. On the other side, municipalities, of course, believe that certain things must be prohibited, and other restrictions should be put on to protect the use and maintenance of the system and the treatment plant.

Actually the viewpoints are not too far apart. There are some problems, but they are not insurmountable. The answer probably lies somewhere between both of the different viewpoints.

Mr. Dobb claims that industrial waste concentrations should be spelled out. It should be pointed out, however, that there are plenty of unknowns and uncertainties still remaining. There are hundreds of thousands of chemicals that are known, and by tomorrow we will have more. Therefore, any attempt to spell out concentrations of acceptable material in the sewer system is almost impossible.

On the other hand, Mr. Steffen contends that the specifications should be general, and the concentrations should be left to technical people. That is an excellent concept, but general standards do not provide practical design limits. The limits that are set up shouldn't be so vague or so general that there is very little to

go on when a decision is necessary as to the kind or the amount of treatment required. No industry should be expected to spend important money on vague generalities.

As between those two viewpoints, the answer must be general because of uncertainties; but where the information is fairly well established, it should be definitely stated in any ordinance or set of regulations.

Mr. Milligan contends that waste specifications should apply to the industrial effluent. This involves certain questions of policy. The public sewer system and sewage treatment plant stands between the receiving waters and the individual user. If the industry or user were on his own, he would be directly responsible for the conditions in the stream, but when connected to a public sewer system, the governmental agency stands between the user's outlet and the stream. In almost all cases, such an arrangement is greatly to the advantage of the user.

Although the standards should apply to the industrial effluent, where the industry is connected to the public sewer system, the requirements should be based on protecting the receiving waters and giving the user the benefit of the dilutional effect of the sewer system.

Mr. Olds takes the position that the specifications should be based on one level of concentration at the treatment plant.

It should be pointed out, however, that some types of effluent can't be considered at the treatment plant; the deleterious effect of that discharge is right at the point where it enters the sewer system. Therefore, whether it should be excluded or included, and to what degree, must be determined at the point of entry and not farther down the system at the treatment plant.

The answers to the problem seem to lie somewhere between the points of view taken by Messrs. Milligan and Olds. For certain types of wastes the standard must be based on the level at the plant; for certain other wastes the standard must be based on the level at the point of entry to the municipal system.

Detroit has been interested in its waste standards and regulations since 1946 and has accomplished considerable in this line. Because of the multiplicity of metalworking industries in the city, ferrous iron caused a lot of trouble, concentrations at the plant frequently running in the range of 30 or 40 p.p.m., and at one time going up to 400 p.p.m. Such concentrations in effect put the treatment plant out of service, so something had to be done to bring them back within a range where treatment was possible at the plant. Whereas the Detroit plant had been suffering from this condition about 10 or 20 per cent of the time, application of the standards has reduced the plant difficulties from ferrous iron to about 1 per cent of the time.

Disposal to Public Sewers *vs.* Separate Treatment

Chairman Watson:—There is still one further area for discussion; that is, where there is a choice, should an industry discharge its wastes into the municipal sewer system with or without treatment, or should it discharge into the stream with or without treatment?

The first speaker considers discharge of industrial wastes to public sewers; the next, treatment of the wastes and direct stream discharge.

N. E. Damron, Sanitary Engineer, Lederle Laboratory Division, American Cyanamid Co., Pearl River, N. Y.:—Sometimes the efficient disposal of an industrial waste can be accomplished by discharging it to a municipal sewer; at other times it is necessary to provide treatment at a company plant prior to direct dis-

charge to a stream. Obviously, if public sewers are not readily accessible, an industrial waste treatment plant is required. Although less apparent, separate treatment of an industrial waste is also necessary if the nature of the waste is such that it can not be treated economically at a municipal works. This might be true if a waste had little B.O.D. but contained pollutants which were not removable by the conventional processes used at domestic sewage plants. Another example is that of an industrial waste which would meet stream standards without the degree of treatment sometimes required on municipal sewage.

Fortunately for consultants and industrial waste engineers, the decision of whether to discharge into a stream or into a public sewer is usually complex: elaborate, lengthy, and expensive studies are often necessary to obtain an intelligent answer. This outline lists a number of the benefits to be derived from discharging industrial wastes into a public sewer. The other side of the question—treatment and direct stream discharge—is to be discussed by another panel member.

As is true of most industrial considerations, cost is of prime importance. Which is the least expensive method of discharge? Which will give industry the most for its money? Usually the combined treatment of industrial and municipal wastes is more economical than separate treatment in a number of small plants. The trend is toward supermarkets and super sewage plants which can handle a large amount of business at a low unit cost.

These joint plants eliminate the need for industry to provide complete treatment. In many instances, where the wastes are not oily, toxic, caustic, or strongly acid, they can be discharged to the public sewer without pretreatment. This is particularly true of small industries whose waste flow is only a small percentage of the total sewage. Where pretreatment is required, the waste facilities can often be kept simple and small in size, thus minimizing capital investment and operating cost. If an industry is located in a city, there may be no room for an extensive treatment works. Even if land is available, it may be quite costly and better used for manufacturing. In contrast, there is usually no problem in obtaining low-cost land for a municipal plant. Discharge into a public sewer eliminates the need for an industry to build expensive outfall sewers.

Industries are usually reluctant to make large investments in waste disposal. This natural reluctance is due to management's desire to obtain a tangible, monetary return on its capital outlays. Money for waste treatment must compete with money for the manufacture of profit-making items. Under these circumstances, management may be inclined to buy its waste treatment on an annual basis instead of making a large capital investment. By sending its wastes to a municipal plant, industry can take advantage of the very favorable interest rates on non-taxable sewer bonds.

Of those industries which are connected to public sewers many pay on the basis of flow, B.O.D., and solids. Should production fall off, or manufacturing processes change so the volume of wastes is reduced, the annual treatment bill should be substantially less. Industry will not be stuck with a "white elephant." Such a cost arrangement provides an excellent incentive in an industrial plant for the conservation of water, re-use and recovery of waste materials, and the elimination of pollutants at the source.

The big sewage treatment plant usually has better supervision and control than a small industrial waste plant, which may not have a full-time superintendent, a chemist, or adequate operating personnel. In some indus-

tries, waste treatment is a part of production and, due to certain union agreements, the operating engineer has no direct authority over the men who work at his waste plant. Almost as detrimental to satisfactory operations is the high rate of turnover among plant personnel—it is hard to retain well-trained and experienced men.

The joint sewage works is usually economical, due not only to its large size but also to the increased treatability of its combined wastes. The classic example of this is the neutralization of an acid waste with an alkaline one, although this has probably occurred in the classroom much more frequently than it has in practice. However, there are other synergetic waste combinations which aid in the settling of solids, the removal of colloids, and the breakdown of organic matter.

Treatability of industrial wastes is often helped by the dilution and nutrition values of domestic sewage. Some wastes, such as those from pharmaceutical plants, have a B.O.D. of 2,000 p.p.m. and stronger. This type of waste can be readily treated on trickling filters, but unless the strong liquids are diluted, heavy growths will build up on the filters, causing many operating problems and perhaps creating very obnoxious odors. Other industrial wastes, such as those from cotton kiering and brewing, are deficient in nitrogen and phosphorus. These important nutrients can frequently be supplied by mixing the industrial waste with domestic sewage. Furthermore, when an industrial waste is mixed with larger quantities of sewage, fluctuations in the composition, strength, and rate of flow are not as important as when the industrial waste is being treated separately.

A number of industries, particularly those concerned with food processing, have a seasonal waste disposal problem. Where municipal plants are available or can be built, food processing wastes can often be treated with year-round sewage. Chemical treatment during the processing season will help to remove excessive suspended solids and B.O.D. Thus, the industry can avoid construction of a waste plant which would be idle much of the year.

Although the discharge to a city system must be carefully controlled, such control is not as critical as direct stream discharge. No matter how careful and conscientious employees try to be, sooner or later an operator will turn the wrong valve—usually at 2 AM—and send a heavy load of industrial chemicals down the sewer. With direct stream discharge this could result in a nightmare of dead fish, outraged sportsmen, and very bad publicity. However, if this inadvertent discharge were sent to the municipal plant, complete disaster would be avoided although the municipal superintendent would be faced with a difficult period of operation and would probably require tighter control at the industrial plant.

Another disadvantage of direct stream discharge is the difficulties encountered in attempting to set up fair effluent standards for a number of industries and cities located on the same stream. After standards have been set, it may be even harder for the industry to meet them as new products are made and old ones discarded. There is also a feeling in industry that water pollution control authorities take a more lenient view in handling municipal disposal problems than they do in the case of industries. Whether or not this is true, there are advantages in handing over to a municipal authority the responsibility and problem of meeting stream standards.

Even when the cost and difficulties of individual treatment appear to be less, combined treatment may still make good sense. By connecting into a city system an industry is aiding

the community to bear the cost of an areawide improvement program. In some smaller towns and sparsely populated districts a public sewer system would not be possible without industry's backing. Under these conditions management obtains the benefits of good will, excellent advertising, and better living conditions for its employees.

In most cases there will be a number of reasons for an industry to discharge into a public sewer. For example, at Lederle Laboratories in Pearl River, N. Y., management was influenced by its desire to be a good neighbor, as well as by the savings involved. Both Lederle and Pearl River are located on the watershed of a public water supply and, as they grew in size, it became desirable in 1939 to build a municipal plant which would handle their combined wastes. Some of the capital was provided by a water company, part by Lederle, and the remainder by WPA funds and municipal bonds. Operating costs were shared by the industry and the town on a flow basis. Due to industry's participation the sewer tax was quite low, only half as much as it would have been otherwise.

When penicillin, and later Aureomycin,* was discovered and the production of these antibiotics was begun at Lederle, the plant's industrial wastes were increased tremendously. To meet this new waste problem, the treatment facilities at the town plant and at Lederle were increased and the contract with the town was revised so that payment was calculated according to B.O.D. strength and volume of flow. During this period of expansion and waste disposal difficulties, Lederle was fortunate to be connected with the town plant. Thus, the public water supply downstream did not receive unmanageable quantities of waste. By 1950 it was obvious that building new treatment units would not provide a permanent solution to the area's waste problem. The best bet was to remove the wastes from the present watershed and transfer them to the Hudson River, the lower part of which is too salty to be used for potable water.

At this point management had the option of going it alone or again joining forces with the town. In either case, Lederle would have to pay the full cost of the project. The initial cost of each method would be about the same; a company trunkline would be smaller, but could not take advantage of existing sewers. Direct discharge to the river would mean losing an investment in the municipal plant and the construction of additional treatment facilities at Lederle. A joint effort by the town and Lederle appeared to be best from engineering, legal and public relations standpoints.

In 1952 a new outfall was built which utilized portions of a former Army camp outfall to the Hudson River. Construction of this outfall not only aided in solving Lederle's immediate waste disposal problem, but also helped to open up large areas for industrial and residential use.

In summary, the main advantages of discharge to a public sewer are:

1. Lower cost due to the large size and better supervision of a single plant.
2. Availability of capital in the form of non-taxable sewer bonds.
3. No duplication of waste disposal facilities.
4. Improved treatability of combined industrial and domestic wastes.
5. Less critical control requirements for sewered wastes as compared with treatment and direct stream discharge.
6. Better community relations.

The objective of getting the job of waste disposal done at the least overall cost to industry and the commun-

* The American Cyanamid Company's trade mark for the antibiotic, chlortetracycline.

ity usually can best be attained through combined treatment of industrial and domestic wastes.

H. W. McElhaney, General Foreman, Finishing Division, Talon, Inc., Meadville, Pa.:—Whether or not industrial wastes are treated prior to discharge into streams is purely a matter of local practice or ordinance; but the fact remains that nine times out of ten they ultimately wind up in a stream or river, even when first discharged into a sanitary sewer.

Therefore, the problem appears to be simplified into two phases.

The first is a question of treatment or no treatment prior to discharge; and second is the manner and location of treatment prior to discharge on the basis of eventual discharge to some stream or river, either directly to the stream or indirectly through a sewer to a city sewage treatment plant and then to the stream. Only one question appears to remain for discussion—the most practical and economical means of pretreatment before discharge, because certainly it must be conceded that some pretreatment is necessary, even if it be only controlled discharge, dilution, or partial treatment rather than complete treatment.

The benefits of direct discharge to a stream by industry may be summarized as follows:

1. In direct discharge only one set of requirements (those of the state where the discharge occurs) must be met. If the city sewer is used, a double standard exists. On the primary one of the city ordinance, usually different in every city and subject to change as the city management grows and changes, is superimposed the secondary one of state requirements.

2. Usually a city requires some pretreatment prior to discharge to the public sewers. With a little more treatment, an effluent suitable for direct stream discharge could be produced, thus eliminating city charges, possible damage to the stream if the city treatment plant fails, and the question of responsibility in case of a spill or slug getting through from one of several industries using the same sewer.

3. No assessment or sewer charge is levied when direct stream discharge is used.

4. Better community relations will exist between the citizens of a city and industry if the population as a whole does not feel that they are paying the bill for disposal of the industries' wastes. Construction costs, too, are higher for a city plant where both domestic and industrial sewages are to be treated in combination.

5. Industry often will have to pay more than the actual cost if the city sewer is used, because methods of determining and apportioning the cost are often crude or unreliable, with only two workable methods—flat rate or quality-quantity basis—generally recognized. Either method can become a burden to industry due to production process changes, production fluctuations, or changed city management personnel.

In conclusion, it would appear that an industry should treat to the extent necessary to meet local stream requirements. As a result the industry would have complete control of the treatment process; would be able to fix responsibility for such treatment within its own organization; would be able to control and forecast costs; and would be responsible to only one master, not two.

John H. McClintock, Humble Oil and Refining Co., Baytown, Tex.:—Although my company's problem is somewhat different from the typical industrial waste problem under discussion here, we would like very much to turn our effluent over to the city. On the other hand, we don't believe that is practical because our effluent

amounts to about 25 m.g.d. and the city's sewage only amounts to about 5 m.g.d.

Actually, we have done a pretty good job with pretreatment, but, as with most cities, the municipal program is lagging a bit. This particular city has several plants, one of which is a primary plant which dumps into the industry's outfall. Perhaps much of the problem could be boiled down to the relative size of the industry and the municipal plant concerned. It makes a lot of difference whether it is the dog or the tail that is being wagged.

Mr. Damron:—I haven't had any experience with discharge of municipal wastes into an industrial system, but it sounds like a wonderful idea. In other words, the municipality pays the industry and the industry enjoys the advantage of running its own plant and getting paid for it.

Royal E. Rostenbach, Chemical Engineer, Hanford Atomic Production Operation, General Electric Co., Richland, Wash.:—Where industry is in a position to make a choice of going into a stream or into a sewer, it should be remembered that in expanding communities and expanding metropolitan areas, to pass up the opportunity of connecting to the sewer may be to lose that opportunity forever, or at least for a long time.

Ralph H. Holtje, Sanitary Engineer, State Board of Health, Indianapolis, Ind.:—Each discussor's viewpoint is influenced by his own experience. The people in industry who have had unhappy experiences with a community will naturally wish to carry out their own treatment; those industries that have had good relations will naturally go that way. So, it all boils down to the primary factor of public relations. If there is a choice, certainly those who have had good experience with the community will lean toward municipal treatment, whereas those who haven't will lean the other way. The trend seems to be for industry to go in with the community, particularly if the industry isn't too large.

Chairman Watson:—That brings up some good questions. Of course, most cities hope to grow and to get new industries. By what procedure can they insure that their sewer system will be adequate to take in the industrial wastes that may be discharged at a later date?

Mr. Dobb:—To take in all future wastes is to be too inclusive, but sewage works should be planned to provide capacity for at least 25 or 50 years. Although they may be financed through service charges and surcharges, additional sewer systems are not the responsibility of the sewage disposal (treatment) section, but of the sewer department in the community or communities affected.

Communities expand only because of business being brought into the picture. Therefore, it is a function of the city to provide the main trunk sewers, and the function of the local community to provide the laterals to get into the main trunk sewers.

Linn H. Enslow, Editor, Water and Sewage Works, New York, N. Y.:—Many of us know communities where the sewage treatment plant is really an industrial waste treatment plant, whatever it may be called. In fact, a case has been known where one type of industry contributed about 90 per cent of the loading on the local sewage treatment plant. Instead of a sewage treatment plant, this installation should be run as an industrial waste treatment plant, with the city paying the industry for the cost of treating its sewage.

Harvey G. Rogers, Director, Division of Water Pollution Control, State Board of Health, Minneapolis, Minn.:—It seems that we are likely to oversimplify the situation with respect to these industries. There are industries that on the basis of the size of the community and the characteristics of

their waste have no choice as to whether or not they must have separate treatment. The wide variety of industries encountered through the range of size of the communities throughout a state means that in each case the large installation must be considered strictly on its own merits.

In Minnesota it has been found that since the institution of service charges the majority of the industries do feel that they know where they stand. It is easier for them to determine their costs on a calendar basis and to pay a service charge. Controlled provision of waste treatment is a function that can be provided by the municipality at a more economical level than can be provided by the industry.

Mr. Milligan:—In Pennsylvania where industry has a choice of treating its own waste or of discharging it to the city sewers for treatment in the municipal plant, it is often necessary to provide primary treatment or other pretreatment which is almost equivalent to primary.

The margin of difference in cost between pretreatment and so-called primary treatment is very slight. But when it comes to a higher degree of treatment, many industries seem to be finding that it is cheaper to treat their own wastes initially, then enter the city sewers for further treatment. In that range they have a lower surcharge.

Mr. Olds:—In that connection at our plant we were faced with two almost insurmountable problems in connection with trying to fully treat our own waste to go into a stream.

In the first place, for the volume to be handled there was not space available anywhere for a treatment plant of sufficient size. In the second place, the consultants were unable to assure construction of a plant which would adequately treat the waste because it was primarily industrial. On the basis that there must be sufficient dilution with domestic waste to make it adequately treatable, rather extensive pretreatment is performed and the rest is put into the city sewer because we of necessity have to.

W. W. Bergerson, Assistant Engineer, Washington Pollution Control Commission, Seattle, Wash.:—What is waste? In the entire discussion so far waste has been accepted per se. Actually, waste is only what isn't immediately usable. Probably the biggest challenge of all is the matter of utilization of wastes and prevention of wastes. In the State of Washington there is particular cognizance of this problem in the pulp industry, which is doing something about it in the form of wastes recovery and reuse.

Chairman Watson:—That is a very pertinent point; the fact that it is obvious to industry that any recovery which has application is certainly a sounder approach than treatment. And recovery is intended to include the circulation and re-use of water.

L. L. Falk, Engineering Service Division, Engineering Department, E. I. du Pont de Nemours and Co., Wilmington, Del.:—There are several practical considerations that an industrial plant must take into account in the matter of direct stream *vs.* sewer discharge. The factors involved will, of course, vary considerably from plant to plant. Accordingly, the relative costs will vary also.

Most industrial plants do not have the choice to make; they do not have both disposal methods available. This is particularly true of many newer plants that are locating away from sewered municipalities. It is also true for many older plants in large cities where the sewer is the only way for discharging waste. It should be pointed out also that some industrial wastes do not discharge either to a sewer or a stream. Such wastes may be disposed of by incineration, solar evaporation, dumping in abandoned mines or quarries, and by under-

ground disposal in suitable geological formations.

As pollution abatement and rehabilitation of the streams of this country progress, industrial plants will be faced increasingly with the alternatives of stream discharge with adequate treatment, or municipal sewer discharge. The choice will depend on many factors. A few of these are as follows:

1. Changes required in plant sewer system to connect to a city sewer. Here might be mentioned the experience of a du Pont plant in a large city that is proceeding with plans to treat its municipal sewage. It will be necessary for the plant either to connect to the city system or to treat its waste for river discharge. Studies were made within the plant to determine the wastes that could be sent to the river, those that could be sent directly to the city sewer, and those that would require some degree of treatment for discharge either to the sewer or the river. These studies clearly indicated that it was most economical to discharge to the city sewer, even when pretreatment was necessary. Several alternate systems for sewer changes within the plant are now being studied in preparation for connection to the future municipal system.

2. Segregation of waste sources. Much of a plant's total sewer flow may be from sources that contribute little or no pollution. Here separation of such sources will benefit waste treatment for either stream or sewer discharge. In the former case, size of treatment facilities and operation are reduced. In the latter case, the sewer charges will be less because of lower waste volume.

An example here is a du Pont plant in a small town now connected to a county sewer system. The plant is separating industrial wastes and sanitary sewage for delivery to the sewer from those that can still be discharged directly to the river, with the approval of the state water pollution authorities. This plant also provides an example showing that the in-plant cost to deliver waste to a municipal sewer may be more than the charges for the use of the sewer. The sanitary sewage is pumped through a force main to the county sewer. It is estimated that the power, maintenance and depreciation costs are about $0.50 per 1,000 gal., compared to $0.06 per 1,000 gal. charged for use of the county sewer. The estimated cost of operating a separate du Pont sewage treatment plant is $0.80 to $1.00 per 1,000 gal.

3. Acceptability of wastes for sewer discharge. Often certain constituents of wastes cannot be discharged to municipal sewers for such reasons as damage to sewer structure, creation of a hazardous sewer atmosphere, or inability of the sewage treatment plant to handle them. In such cases, segregation or pretreatment of wastes (for example, neutralization of acids or precipitation of metals) may be required. The possibility that a treated waste could be discharged either way should be considered.

4. Comparative operation costs. Normally, sewer discharge will show the lower operating cost over treatment for direct stream discharge. Labor, maintenance, insurance, and depreciation costs are lower. Some examples of cost figures in the literature and within our experience can be cited. Zack [1] indicated that municipal sewer charges for milk wastes in several small Pennsylvania towns ranged from $0.10 to $1.00 per 1,000 gal. of waste. Beebe [2] showed the cost to treat a soluble oil waste by pressure flotation

[1] Zack, S. I., "Treatment and Disposal of Milk Wastes." THIS JOURNAL, **25**, 2, 177 (Feb., 1953).

[2] Beebe, A. H., "Soluble Oil Waste Treatment by Pressure Flotation." THIS JOURNAL, **25**, 11, 1314 (Nov., 1953).

was $0.42 per 1,000 gal., including chemicals, labor, and power, but no depreciation. Liontas [3] gave a cost of $1.10 per 1,000 gal. to treat organic and fermentation wastes on high-rate filters. This included labor, maintenance, depreciation, insurance and overhead. Watson [4] indicated the cost for treating metal-finishing wastes was $0.91 per 1,000 gal. without, and $2.85 per 1,000 gal. with depreciation included.

In constructing a large office building in a suburban location, the du Pont Company chose discharge of sanitary waste to a county sewer over separate sewage treatment for discharge to a nearby stream. A portion of the cost to extend a trunk sewer more than 2 mi. to do this could be justified on the basis of lower operating costs in using the sewer. For example, it costs $0.06 per 1,000 gal. of sewage discharged to the sewer. It would probably have cost at least $0.85 per 1,000 gal., including depreciation, to treat the sewage adequately for stream discharge.

At a new du Pont plant in a remote location, sewage treatment costs will amount to about $0.70 per 1,000 gal. This will include labor, power, maintenance, depreciation and supervision. Here no municipal sewers are available. However, if they had been, in all likelihood, they would have been used.

In conclusion, where municipal sewers are available industries will usually find it advantageous to use them rather than to treat separately for river discharge. In fact, the lower treatment costs and, often, lower initial investment for facilities offered by using municipal systems, is a definite attraction to industrial plants. Industrial plants should expect to pay the full cost involved in treating their wastes after discharge to the city sewer. It should be pointed out that municipalities, because of the lower unit investment cost of large treatment plants and the lower interest rates they pay on their bonds, are in a position to do this more cheaply than industry, which must bring in a higher return on its investment because of the risks involved in competitive enterprises. Also, because of the dilution of industrial wastes in municipal sewers, treatment by the municipal plant is rendered easier in many cases than it would be in the connected industrial plants.

[3] Liontas, J. A., "High-Rate Filters Treat Mixed Wastes at Sharp and Dohme." THIS JOURNAL, **26**, 3, 310 (1954).

[4] Watson, K. S., "Treatment of Complex Metal-Finishing Wastes." THIS JOURNAL, **26**, 2, 182 (Feb., 1954).

FEDERATION HEADQUARTERS OFFICE MOVED

At the end of April 1955, the Federation headquarters and publication office was moved from its former location in Champaign, Ill., to new quarters in Washington, D. C. The new address is:

Federation of Sewage and Industrial Wastes Associations
4435 Wisconsin Avenue, N.W.,
Washington 16, D. C.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

1954 OPERATORS' FORUM *

CARL C. LARSON, *Leader*

Chemist, Springfield Sanitary District, Springfield, Ill.

Biocatalysts

H. Heukelekian, Professor of Sanitary Engineering, Rutgers University, New Brunswick, N. J.—I want to make it clear, so that what I say will not be misinterpreted, that I fully recognize the importance of enzymes and bacteria. Without enzymes there is no biochemical activity. Enzymes lie at the base of all life, plant, animal, microorganisms and otherwise, and without bacteria we have no biochemical activity either. Bacteria do produce the enzymes. They produce many enzymes. They produce these continuously, so that there cannot be bacterial activity without enzymes, although there can be enzymatic activity in the absence of bacteria. The subject under discussion is the artificial addition of bacteria and enzymes for the purpose of stimulating and promoting biochemical activity.

I have been rather skeptical about this process of addition of so-called "biocatalysts" for the purpose of promoting biochemical activity. There are two independent approaches that give rise to this skepticism. One approach is the experimental, the other theoretical. I want to say something about each.

There are two kinds of experiments reported on this question of biocatalysts: carefully controlled laboratory experiments, and sewage treatment plant experience.

As early as 1930, considerable work was done at Rutgers University on the addition of enzymes for the purpose of stimulating sludge digestion, and was reported in a bulletin of the New Jersey Agricultural Experiment Station, New Brunswick, N. J. At that time it was not possible to show any appreciable significant increase in activity as a result of the addition of enzymes. Additional work reported recently (see THIS JOURNAL, **25**, 11, 1259; Nov., 1953, also gives negative results from the addition of pure enzyme preparations and from the addition of some of the commercial preparations that have been promoted in the field. The studies have failed to produce a substantial increase in activity. In addition, others have done carefully-controlled work with similar negative results.

The other type of evidence comes from plant work where, for some reason or other, enzymes or biocatalysts were added to certain portions of the sewage treatment process and some claims of advantage are reported.

It is difficult to arrive at a conclusion on the basis of treatment plant experiments, because the evidence is rather unconvincing when there are no controls. Moreover, there is no way of proving that the advantages or the

* From transcript, 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

The first section of this Forum, covering the subject of salaries and job classifications for sewage treatment plant personnel, appeared in THIS JOURNAL, **27**, 4, 495 (April, 1955).

benefits claimed were really due to the addition of the biocatalysts rather than to some other uncontrolled conditions that might have arisen at the same time. Until plant-scale work is done where the advantages claimed are compared on a parallel basis with an adequate control, simultaneously run without the addition of a biocatalyst, then this kind of evidence cannot be taken very seriously.

On a theoretical basis, there are a number of reasons why enzymes and the addition of cultures are not indicated in the sewage works field.

There are three general types of enzymes. The first is the hydrolytic enzymes that the organism produces and secretes out of itself into the surrounding medium. These exocellular enzymes bring about the breakdown of complex organic materials to a state where they become available and can diffuse into the cell. After these hydrolytic enzymes have worked on the complex organic materials and made them diffusible and entered into the cell, a second type of enzymes comes into play. This second group break down these diffusible organic substances within the cell for the purpose of energy liberation, for assimilation, and for synthesis. This reaction, called respiration or fermentation, is an energy-liberating reaction. The energy produced from this step then is used in synthesizing new cell material by a series of other enzymes.

Hydrolytic exocellular enzymes can readily be obtained from plants and animals, and certain hydrolytic changes can be brought about by these enzymes in the absence of living cells. But it is not correct that the hydrolytic changes brought about by these enzymes are faster or that similar changes cannot be initiated by the development of a natural population with their complete enzyme systems. Living cells continuously produce numerous enzymes to carry on their vital activities. These vital activities result in the stabilization of waste substances. The process, therefore, is self-perpetuating. The addition of enzymes is at best merely a temporary expedient, because the artificially added enzymes rapidly become inactivated and destroyed. Therefore, one must rely on the continuous addition of these preparations. Even as a "starter" these enzymes are of doubtful value in reducing the maturation of a new waste treatment plant or unit. Unless the waste is sterile, the necessary population establishes itself just as readily without the addition of enzyme preparations. Even with sterile waste there are other more readily available and economical sources of inoculation. If the sterility of the waste is due to the presence of inhibiting substances, the addition of enzyme or bacterial preparations will certainly not be of any value. The addition of such preparations for remedial and corrective purposes cannot be of any help unless the causes of the trouble which gave rise to the difficulty in the first place are removed. When this is done the normal population will begin to function again.

To bring about complete stabilization of waste materials by means of enzymes is tantamount to claiming that all the functions of a living cell can be reproduced artificially by enzymes. It is true that certain transformations and degradations have been brought about by enzymes in the absence of living cells, such as conversion of starches to sugars and sugars to alcohols and proteins to amino acids. Yet as far as I know, no one has been able to break down these or other organic compounds completely to CO_2 and water by pure enzyme preparations. Complete oxidation and stabilization are phenomena related closely to the synthetic and vital activities of a cell.

When certain specific fermentations, such as alcohol fermentation by cell-free enzymes are undertaken, a specific raw

material such as sugar is used under the proper pH conditions, and the result is alcohol. This can be done by pure enzyme preparations, but the efficiency of even this simple process is lower than similar fermentation brought about by living yeast cells. The accomplishment of the fermentation by cell-free enzymes constitutes a significant contribution to scientific progress, but under practical commercial conditions alcohol is still being produced by yeast and not by cell-free enzymes. How fantastic it is to claim that wastes of much more complex and varied characteristics than simple sugars can be destroyed by means of any number of artificially added enzymes! The foregoing statements apply as well to the claims made in regard to the addition of living cells.

Let us start with the fact that microorganisms are ubiquitous, and that they surround us no matter where we are. They are found in the air, water, soil, food, and sewage. In fact, it requires special precautions to exclude them completely. This fact, along with the corollary that under favorable conditions microorganisms multiply rapidly and attain very high population levels, is the basis for the development and maturation of a suitable population for any waste to be treated by any process. The necessary original organisms are present as contaminants in the waste itself provided the waste is not sterile and does not contain toxic substances. The artificial addition of preparations of living cells to sterile wastes will prove of some value. In other words, when the bacteriologist makes a culture medium and sterilizes that culture medium, it will remain sterile as long as air and microorganisms are excluded from it by the common precaution of putting in a cotton plug. It is necessary, under those conditions, to introduce an inoculant. There conceivably may be situations like this, where the waste is absolutely sterile. In that case the artificial addition of bacterial preparations may be useful, but there are cheaper sources of inoculum than artificial cultures. Why buy these artificial cultures? Their value is no greater than can be obtained from any number of other sources, such as inoculating with sewage and soil. To add cultures to wastes that are sterile by virtue of their containing some toxic material, is wasteful. Soil has a great variety of microorganisms capable of utilizing various materials. It has been possible to develop from domestic sewage, cultures capable of destroying formaldehyde, phenol, and other toxic materials, which are not normal constituents of domestic sewage. If the artificial culture contains only a few specific types of microorganisms, it is quite likely to be of limited value because of the heterogeneity of the compounds present in the waste materials. The compounds present in the waste materials and the specific organisms required to attack these compounds are not known. At best the artificial culture preparation can be only a hit or miss proposition.

In conclusion, it should be repeated that the over-all consideration is to control the desired environmental condition at an optimum. The organisms will become established and perpetuate themselves without the aid of outside cultures, provided the substratum is not sterile nor does it contain toxic materials.

Walter A. Sperry, Superintendent of Sewage Treatment, Aurora, Ill.—I could sum up my remarks in the one statement that we found nothing to confirm the claims made by those who are advancing the merits of biocatalysts. Moreover, I was privileged to have correspondence with four other men in Illinois who were similarly interested in these substances; Messrs. Kraus of Peoria, Hatfield of Decatur, Carlson of Rockford, and Meers of Chicago Heights. All these

men furnished information on their experiments. In the case of Kraus, Carlson and myself, we performed bottle experiments. I am sure these bottle experiments were performed conscientiously and carefully, and the net result was nil. At Aurora, (Ill.), in November 1952 18-day, 20-day, and 21-day bottle experiments were performed in 1 gal. digesters, being careful to charge the digesters with raw primary sludge in direct ratio with the sewage treatment plant digesters. Each experimental digester had a control, and accurate determinations were made of the volatile content, the total solids, and the solids added. At the end of the test we evaluated most of the characteristics—pH, specific gravity, reduction of volatile solids, and total solids—of the residual sludge. In all cases there was no variation beyond 1 per cent, between the control and the enzyme treated digesters.

The ladies' toilet at the plant was converted into an incubator room because it was easy to close the door, turn on the radiator and have a constant temperature of 90° to 95° F. all the time. Then two 10-gal. digesters were built and another series of experiments was run. The tests were repeated with the 10-gal. and 1-gal. digesters, with similar results, particularly on the 10-gal. digester. In the first series of experiments with gallon digesters, efforts were made to adjust the doses to the recommended dose of 1 lb. per 1,000 cu. ft. Later, after correspondence with the suppliers, the dose was increased considerably on some theory that for small experiments the dosage must be increased. Finally, we just quit, because there appeared to be no value in bothering any further.

Kraus, of Peoria, went a little further in the analytical work. He observed that with the addition of 0.35 to 3.2 lb. of biocatalyst per 1,000 cu. ft. of sludge per week, and with digestion periods of 5½ to 19½ days, the quantity of gas produced and the conversion of organic nitrogen to ammonia was of the same order as the controls. This was well within the limits of accuracy and reproducibility of the experiments.

In further tests the biocatalysts produced gas in proportion to the volatile matter that they contained. Extremely large doses of these materials produced no additional gas, other than that produced from the volatile matter they introduced into the digester.

Carlson of Rockford (Ill.) reported that his digestion experiments had not produced any results.

Meers of Chicago Heights (Ill.) adds that he had the unfortunate experience of having an unwise salesman dump a biocatalyst into the primary clarifiers at the sewage treatment plant during his absence. Nothing resulted.

Hatfield was fortunate in obtaining 1,000 lb. of a biocatalyst from a manufacturer for a plant-scale trial. In his report summarizing the findings he concludes that the plugging of the aeration plates was apparently due to a material which was not subject to hydrolysis or destruction by enzymes. A total of 131 lb. of material was used, in repeated dosages of 1.4 lb. per 1,000 cu. ft., on three successive days, and on a fourth day seven days later. This material was aerated three days and then passed into the activated sludge system, where it seemed to have no effect on the activated sludge process.

Furthermore, the activated sludge wasted after this treatment showed no increased activity, although the concentration of biocatalyst remaining was small when the contents of the one tank were mixed with all the sludge.

Three attempts were made during 1952 and 1953 to stimulate digestion of activated sludge in the heated digestion tank. This tank has a capacity of 44,500 cubic feet, and was treated

with 50 lb. of biocatalyst on December 9, 1952, and again on January 7, 1953. The material was worked into the scum at the gas collecting dome. The scum which was not thick, all went down, but this could have been caused by the paddling and mixing action. There was no increase in gas production following this treatment.

In May, September and November 1953, the biocatalyst was introduced into the digester with the incoming sludge in 50-lb. amounts, or at the rate of 1.1 lb. per 1,000 cu. ft. A careful study of the rates of gasification, as measured through a standard displacement meter, did not indicate an increase in biological action that would produce gas. There was no visual improvement in the operation of the digestion tank. A slight improvement in hydrolysis without gas production might have been obtained, but this cannot be proved from volatile matter determinations.

Dr. Hatfield concluded his letter with the statement that no favorable results could be reported.

John S. Wiley, Senior Sanitary Engineer, USPHS Communicable Disease Center, Savannah, Ga.:—The personnel of the Communicable Disease Center have had practically no experience in the use of biocatalysts in sewage treatment and a very limited experience in their use in the composting of organic wastes. However, a study of the latter is included in the agenda of a research project and therefore there is a considerable interest in the subject. The project, under way since July 1953, consists of investigations in conversion of organic wastes to usable by-products to eliminate disease vectors and is concerned primarily with high-rate, thermophilic, aerobic composting of garbage and refuse and other organic wastes, including sewage sludge.

No conclusive experiments have been conducted at Communicable Disease Center regarding the addition of organisms or their enzymes. Initial studies have been conducted in small batch-type mechanical composters in which garbage and refuse from the city dump is composted with slow continuous stirring and the addition of air. Attempts were made to secure optimum conditions for composting in a few days and the Earp-Thomas "starter," containing bacterial inoculum, was used in most of the initial mixtures. Normal temperature curves showed an increase to about 110° to 120° F. the first day, a plateau extending for about a day, followed by an increase to 130° to 159° F. on the second to fifth day, and finally a slow decline to within 10° of ambient temperature in a total of 4 to 10 days. Moisture and carbon dioxide production both closely correlated with temperature. The pH generally was 4.5 to 6.5 initially, holding steady or dropping during the first day or two, then climbing to 8.0 to 8.5 and dropping to 7.5 to 8.0 at the end of the run. The addition of limestone or slaked lime did not seem to affect pH much except initially and did not appear to speed up the composting process. In the composting runs, total weight decreased an average of 37.5 per cent; dry weight, 36.3 per cent; moisture, 38.9 per cent; and volatile solids (combustible matter), 41.6 per cent.

With the starter, good compost was obtained in 5 to 9 days. In two experiments without starter (no inoculum), one batch resulted in poor compost with no thermophilic action occurring in 7 days, and the other resulted in good compost with normal temperatures but required 10 days. No experiments have been made in which only the bacterial cultures have been added, so that the effect of the starter containing inoculum has not been compared to inoculum alone. It may be that any benefits attained from the starter were due to one or more of the starter ingredients, rather than to the inoculum.

Subsequent test runs comparing the starter to the addition of compost from previous runs indicated that the latter was equal to or better than the former. For this reason compost from previous runs is now used to seed the raw garbage.

Bacteriological tests using plate counts at 50° C., were made in which inoculum was compared to other materials. These results indicate that thermophilic bacteria, actinomycetes and fungi were present in much smaller numbers in the inoculum than in raw garbage or finished compost. The counts also indicate generally an increase in thermophilic organisms during the composting process.

Ross E. McKinney, Assistant Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.:—A survey of the published information available in the literature and in the manufacturers' bulletins concerning biocatalysts has been published (see *Eng. News-Rec.*, Oct. 1, 1953). Since then, an attempt has been made to tap the wealth of information on the subject that is available in the files of sewage treatment plant operators who have used the product.

We couldn't write to every sewage treatment plant in the country, so we went to our second source, the state sanitary engineers, most of whom were well aware of the important operating difficulties in their district. They were also aware of any attempts to alleviate the operating problems and were on the lookout for any new methods which would help somebody else in another district. Inquiries were sent to each of the 48 state sanitary engineers and the territorial engineers of Alaska and Hawaii. A 62 per cent reply was obtained, which can be considered quite satisfactory for this type of survey. Some of the replies indicated particular people to write to for additional information. The results reported by the state sanitary engineers from the operators in the field were approximately two-thirds negative and one-third positive (see Table I). In this use "positive" does not mean that there were controlled experiments carried out carefully with plenty of data to show that the biocatalysts worked or did not work and the quantitative results. By "positive" it is simply meant that the operator was satisfied that after the use of the biocatalyst something happened in the plant so that he was pleased with the results rather than displeased.

It is due to the so-called apparent success or failure of the biocatalyst that there is room for discussion of these particular products. I would like to elaborate on one particular problem that faces the operator and possibly may explain why the biocatalysts have worked in some cases and have failed to work under supposedly identical situations.

Take the case of sludge digestion, since it is quite near the hearts of almost all sewage plant operators. The digester is usually a rather large tank that is quite sensitive to almost anything done to it. The usual problem comes from too rapid addition of organic matter. There is one little group of organisms in the digester that can really tear into the organic matter and produce organic acids as their end product. Normally in a properly operating digester, the acids are quickly neutralized by buffering compounds and then metabolized to methane and carbon dioxide by methane-producing organisms. A lack of buffering compounds and methane bacteria will allow the acid to build up from this first group of organisms. This is usually indicated in the operating data by a drop in pH, because most operators do not make the volatile acids test. When volatile acids determinations are run an increase in acid usually will be noticed before the pH drops. If the pH drops much

TABLE I.—Summary of Reports by State Sanitary Engineers on Biocatalyst Usage

State[1]	Problem	Type of Biocatalyst	Results
Alabama	Odor from sewers	——	No success
Arizona:			
Motels	Clogged seepage pits	Enzymes	Improved operations
Navajo Ord. Depot, Bellmont	Foaming, odors, solids carryover, poor digestion	Enzymes	Foaming ceased, odors reduced to normal, solids settled, dig. normal first time in two years
Connecticut	Sludge digestion	——	No success
Florida	Odors from lagoons treating citrus wastes	Bacteria	No success
Idaho	Sludge digestion	——	Increased gas prod.
Illinois	Three laboratory experiments on sludge dig.	Enzymes and bacteria	No success
Iowa:			
Seymour	City septic tank	Enzymes	Decreased amount of sludge drawn; drained more easily
Spencer	Digester scum	Enzymes	No success
Louisiana:			
Leesville	Septic sewage and digester trouble	Bacteria	Freshened incoming sewage; decreased scum
Lake Charles Air Force Base	Grease traps	Bacteria	No success
Minnesota	Sewage disposal systems	Bacteria and enzymes	Varied from no success to satisfactory
Missouri	Sludge digesters	Enzymes	Gas production increased immediately after treatment but leveled off; sludge thin and in one case caused an odor problem
Montana	——[2]	——	No success
New Mexico	——[3]	——	Caused foaming problem
Oklahoma	Septic tank odor, digester scum	Enzymes	Odor eliminated, reduced scum thickness
South Carolina	Starch wastes	Enzymes	Hydrolysed starch wastes and permited disposal by soil seepage
	Sizing wastes in digester	Bacteria	No success
Texas	——[4]	——	——
Utah:			
Intermountain Indian School, Brigham City	Grease and acid digester	Enzymes	Slight increase in gas; sludge denser; pH unaffected
Univ. of Utah	Laboratory digester experiments	Enzymes	Increased gas production only after pH adjusted; gas 62% CO_2, control 26%
Virginia:			
Pimmet Serv. Co., Fairfax Co.	——	Bacteria	No success
Roanoke	Digesters	Bacteria	Good gasification, pH never below 6.5; control dropped to pH 4.5
Hampton Roads	Digesters	Bacteria	Immediate increase in gas but soon receded, pH dropped to 5.2, vol. acids up to 3700 ppm

[1] The state sanitary engineers of Alaska, Delaware, Georgia, Hawaii, Indiana, Maine, Massachusetts, New York, North Dakota, Ohio, Oregon, Rhode Island, South Dakota and West Virginia reported no reports on the usage of biocatalysts in their territories.

[2] Two cities reported usage.

[3] Three cities reported usage.

[4] Survey of usage now underway by State Health Dept.; laboratory studies carried out by State Health Dept. and Univ. of Texas.

below 6.0, the acid-forming bacteria are adversely affected by this unfavorable environment. The methane bacteria are already lost and the operator suddenly wakes up to the fact that something is wrong with the digester and he has to do something with it.

Now, this usually happens in the older digesters where there isn't any mixing device to stir up the contents and keep everything uniform in the tank. The operator usually does not have external heat exchangers to recirculate the digester contents, or the proper facilities for pumping sludge. Accordingly, he is faced with the problem of doing something with the sludge and he still continues to add it hoping that something will happen to make everything alright. Actually, the mere addition of enzymes or bacteria to the digester will not start microbial action again unless the environmental conditions in that digester are changed at the same time.

By first adjusting the digester pH properly, it is possible in some cases to add certain biocatalysts and affect an increase in microbial action, provided the total population of the organisms has already been reduced. If the proper number of organisms are already in the digester, the addition of a few more will not have any effect. The mixing of the biocatalysts appears to be the important item in laboratory and field experiments. Most of the biocatalysts have a small capacity to adjust pH. When they are added to a digester without rapid mixing they can remain concentrated in a sludge. The pH in that particular sludge material, depending on diffusion, is usually higher than the sludge or the liquid surrounding it. The organisms, if any are present, can work on the organic matter. There can be a slight breakdown of the organic matter with the liberation of buffering compounds, ammonia primarily, which react up with the CO_2 and form ammonia bicarbonates, which could cause an actual neutralization of some of the material in the digester. If this relatively slow cycle went on long enough, it would be possible to re-establish satisfactory conditions in the digester.

In many cases this slight buffering action seems to have been a factor in the re-establishment of certain digester operations. In other cases, where better mixing facilities diffused the material completely through the sludge, there was not enough buffering action by the biocatalysts to affect a change in pH. This action was completely lost because the biocatalyst, the organisms, or the enzymes were affected by exactly the same factors which were affecting the original organisms in the digester. Based on the physiological concepts of the microorganisms involved in sludge digestion, the correct procedure for re-establishing normal operations in an acid digester is to neutralize the acids with lime, ammonium bicarbonate, or some other suitable base to a pH of 6.5 or greater, and maintain that pH with proper buffer control. In most cases, seeding the neutralized sludge with the proper bacteria obtained from a biocatalyst or from actively digesting sludge will speed up the recovery process.

The choice of microorganisms is primarily one of economics and operation. Some operators prefer to use the commercial biocatalysts rather than digesting sludge, because of the ease in handling. But at the present time, none of the commercial biocatalysts have been shown to contain more of the active organisms necessary for good sludge digestion than actively digesting sludge obtained from a properly operating digester.

F. W. Gilcreas, Assistant Director, Division of Laboratories and Research, New York State Department of Health, Albany, N. Y.:—Professor McKinney brought out the crux of the problem when he said that sewage contains all of the biologically active components

necessary for good digestion of the solid materials. It is only when the sludge is abused by adding too many solids to be digested or when there is interference with the environmental conditions which control the activities of those biologically active components, that trouble results. Therefore, the problem is more a matter of controlling the environment than it is of stimulating or adding to the biological components present. Certainly if the environment can be controlled the bacteria that produce the enzymes will do their work well and will not expect some shock troops. The thing that has puzzled me is whether or not the introduction of biological components is really an effective means of stimulating digestion, providing the environmental conditions are right. One or even a group of the biologically active components may not be particularly concerned with the sewage and the composition of the sludge.

One of the earliest ways of starting sludge digestion has been to seed a new tank with sludge from another treatment plant which is properly operated. Certainly an important part of the technique of making a B.O.D. test is to provide seed if the sewage contains materials that will interfere with proper digestion. The seed is supplied by adding mixed flora and fauna from some other source; not by adding previously prepared materials.

On the other hand, in certain industries the use of these prepared cultures is effective. It does seem that the problem is one of controlling the environment and letting the little bugs work efficiently, rather than to add these laboratory or industrially produced components. Unless the environment is properly controlled even these laboratory components will not function.

George A. Jeffreys, President, George A. Jeffreys and Company, Inc., Salem, Va.:—It appears that the purpose of adding commercial enzymes to a digester is to increase the efficiency of the digesters by reducing the B.O.D. It is assumed that these enzymes together with those produced by the bacteria present solubilize the solids, which are then consumed by the microorganisms and in turn this reduces the B.O.D. of the liquid. The solubles are converted to gas and a more or less stable sludge composed of microbial cells and mineral ash.

The purpose of adding cultures is not only to supplement the bacteria present, but also to seed the digester with the right type of bacteria should none or few be present, as in a dead digester. This is to start the digester going or increase its action. Obviously, cultures will not increase the efficiency in a normally functioning digester.

Enzymes were used in most of the experiments at Rutgers University. To properly convert the solids to solubles, the amount of enzyme that should be used would have to be ten times more potent than standard potencies.

The yardstick used for evaluating cultures or enzymes in the absence of gasification was the production of higher B.O.D.

Neither the enzymes nor the solubles produced would be of value unless the bacteria were present in sufficient numbers to convert the solubles into bacterial cells and gas. Hence, it is apparent that the use of B.O.D. as a yardstick is of no value unless the solids as well as the gas are measured. Digestion could be extremely good while the B.O.D. could remain constant, increase, or decrease. This is because there is a constant conversion going on in which the raw solids are being converted to gas and stable solids. If there is no gasification, the microbial action or digestion would eventually come to a halt due to the toxins produced.

Of course, the final deduction that

enzymes *per se* are of no value is correct, but the methods of procedure would not prove it.

All enzymologists and biologists know and understand that enzymes do not reproduce themselves. Of the group of enzymes experimented with, there are certain standard values established and the amounts required to accomplish a certain digestion are known and can be easily estimated. Based on these facts, any biologist will understand that it would be prohibitive to use enzymes in a large digester.

The statement was made that the necessary bacteria are already present in raw sewage, and by producing proper environmental conditions, they will establish themselves in predominating numbers. In theory and under certain conditions that is true, but that does not state all the facts. Disregarded are the principles of mass inoculation, immunity, antibiotics, toxins, virulence of specific groups of organisms, and changing environment. It is impossible to go into any detail.

In walking down the street most people breathe in a few germs of tuberculosis or streptococcus, but their bodies are able to throw off the effects. However, if the body is exposed to massive doses the invading organism usually overcomes the body's defenses.

Of course, no inoculant cultures are needed if the digester is working to its highest efficiency, any more than a robust person that eats properly needs vitamin pills. However, many digesters are barely digesting, just limping along or just plain dead. What are you going to do? Spend a few thousand dollars pumping it out? Does this mean that a mass inoculation will not do any good, particularly if some corrections are made in the environment? It is also possible to haul some sludge from a distant treatment plant, but this costs more money.

An analysis of a biocatalyst would reveal a concentration of 2,000,000,000 or more anaerobes and facultative anaerobes per gram of the predominating types present in digesters. As many as 30,000,000,000 organisms per gram have been attained, and which remained viable for as long as six months.

The predominating bacteria present in an active digester are not the predominating type present in sewage sludge and, in fact, may be entirely absent. The environment of raw sewage is different from that of a digester, and hence produces a breed of different organisms than is present in a digester.

There are a great many things that can make a digester go dead or lose efficiency, but certainly to close one's eyes and say there is nothing that can be done to correct conditions is absurd and contrary to scientific research.

Suppose the right bugs are not there? Certainly a few bacteria will not do much good. What is needed are billions of them. This requires mass inoculation. What I am hoping is that by improved production methods a biocatalyst can be produced economically and the price so reduced that a dose of even one ton to a dead tank would be economical.

Professor Heukelekian:—It is difficult to reply to a discussion of this sort. Let me explain the experiments that were reported in *Sewage and Industrial Wastes*. The theory in using the B.O.D. of the supernatant liquor as an index of the value of the addition of biocatalysts is that the only way a biocatalyst could be active is by liquefying and hydrolyzing the solid complex organic materials. The complex organic materials in the sludge are liquefied and transferred into the supernatant liquid, and can be determined by the B.O.D. test. In order to make everything in favor of the biocatalysts, the sludge was sterilized so that there would be no effect traceable to bacteria and en-

zymes originally present in the sewage sludge. The sludge was carefully incubated with the addition of many times as high a concentration of these biocatalysts as indicated by the manufacturer. Separation of the liquid was performed in order to assay if there had been any organic material that had spilled over from the sludge to the liquid, by using the B.O.D. as an index. That was one method of approach, but not the only method.

Gas production also was used as an index to see whether any of these biocatalysts had been active or not; and the results were again negative. I would like to know what the specific organisms are that are responsible for sludge digestion, and who has been able to isolate and name them. As long as the organisms are not known, how can claims be made that the organisms responsible for sludge digestion are being added?

Lloyd R. Setter, Sanitary Engineer, USPHS, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio:—Everyone is aware of the necessity, under certain circumstances, of causing bacterial action to proceed with a starter. Sewage solids are the waste of humans, and in a sense, partially-digested sludge before they are received at the treatment plant. Therefore, the use of digested sludge or any other pure culture material is valueless. By starting the sludge digestion slowly, over a period of days, fermentation can be developed from the saprophytic organisms that are normally present in sewage, and particularly in the raw sewage sludge.

Chairman Larson:—At Springfield (Ill.) we never have resorted to any seeding material to start a digester. Digestion was started slowly and the bacteria eventually took hold.

Clair N. Sawyer, Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.:—Within the past couple of years I have become much interested in this problem of "stuck" digesters. Some work has been done at M.I.T. on liming, or the revival of liming of digesters (see THIS JOURNAL, **26**, 8, 935; Aug., 1954). In one situation, not previously described, a digester had been stuck for some time and we thought it would be interesting to see if digestion could be started by means of lime. The same successful technique used previously was tried. The lime was added in various quantities, based on the volatile acids content. Each of the little digesters to which lime was added remained dead for a period of at least six weeks. By that time we were convinced that liming was not the sole answer. What we did then was to add a little digested sludge to each digester, with the result that they all started digesting. That is an excellent illustration of the fact that the culture had been lost. These digesters had been stuck so long that the methane formers had succumbed. Facilities were not available for making actual counts of methane formers, but the fact that small quantities of digesting sludge could be added and have the digesters come to life again was a real revelation.

Robert T. Baer, Baer Products Company, Long Branch, N. J.:—It would seem that we are at a point in civilization where biocatalysts can definitely prove to be of great benefit to mankind in general. Biocatalytic products are in the same phase as the vitamin was some years ago.

Something which hasn't been mentioned in regard to sanitary waste is the grease problem. I have seen the common grease trap, which has been such a problem from the sanitary point due to clogged sink lines and odors, rectified time and time again through the use of biocatalysts, if not in 100 per cent of the cases, certainly in a sufficient number to prove the success of these materials.

In sewage problems in general, where the cost is so high in attempt-

ing to rectify various conditions, biocatalysts have come along in the capacity of something that is still more or less on the ground floor. In two years there have been improvements in these products, and it is certain that the improvements have provided something beneficial in alleviating certain specific problems. These benefits have meant savings to the taxpayers by eliminating the high cost of sewage treatment plant expansion.

The sewage treatment plant at Glendale, Ariz., was saved thousands of dollars through the application of a biocatalyst. It was a typical condition found in plants 20 to 30 years old, located in cities that have gained in population and where the original facilities have become overloaded. Generally, the cost involved in correcting this condition has been tremendous. This is a common problem of great importance to taxpayers everywhere. Whether or not this is the time to draw conclusive evidence on the merits of biocatalysts is something that has yet to be answered satisfactorily. By the same token, there is at least conclusive evidence that benefits and aid have been given various installations endeavoring to solve the extremely intricate problems of plant expansion.

Abraham J. Krell, Technical Director, Reliance Chemicals Corp., Houston, Tex.:—The introduction of preserved cultures has been more difficult than the presentation of any problem that I have experienced. The use of preserved cultures in waste treatment is related to the technique of the fermentation industries; namely, mass inoculation. Actually, the history of fermentation as an art is more than 3,000 years old; the history of sanitary engineering as an art and technology is less than 100 years old. The history of microbiology as a science dates with Pasteur, just about 75 years ago. There are a number of factors involved in the presentation of a new product and new technique. The use of preserved cultures in some ways is a comparatively new idea to the entire sanitary engineering profession.

The number of factors involved in presenting such a method should be considered. First of all, there are problems that have not been solved in sewage treatment and yet remain to be solved, because the entire history of sanitary engineering is a conglomeration of many other sciences that now is emerging under an integrated heading of sanitary science. The basic approach of the sanitary engineer for the past 50 years was primarily epidemic control. He can now turn his attention to fundamentals in biological process engineering. The development of water-carried sewage created a tremendous problem in the rapid spread of disease. The development of the wet process in industry has seen its culmination in the United States and it has brought about a problem in the utilization of water. Some of these problems have not received the basic attention of fundamental research in the universities that they require. Efficient resource utilization is an important national problem.

In working out biological techniques for an industrial waste, I ran into the problem of toxicity of organic wastes. When the pilot treatment plants ceased to operate satisfactorily the idea occurred that if a person could take the adjusted microorganisms that had been developed over a period of time, and placed them in the biological environment that first produced them, it would be possible to start a waste treatment plant up again. Here the use of a desiccated culture of adjusted organisms applied on the principle of mass inoculation would have helped. However, the ideas existing in the sewage treatment field were crude. There are many crude ideas still in this field, and the existing reagents, and other chemicals have not solved them all. It is difficult to realize the enormous

amount of work, crossing several fields of science and technology and engineering economics, and thinking that has gone into the development of biocatalysts. Many small treatment plant operators are seeking solutions to problems that only a small portion of the academic world has considered.

The cost of preserved cultures *versus* sludge as a seed, is an interesting problem. As a consultant I have recommended to some industries starting waste treatment plants along the Gulf Coast that they use marine sediments, which contain mixed communities of microorganisms and are efficient in the utilization of the more complex compounds. However, there are the problems of bringing the marine sediments inland, carrying them in special equipment, and supplying the nutrients. With our technique a marine sediment, with all its conglomeration and richness of life, can be reproduced, desiccated and brought to the treatment plant. This has been done in many industrial plants where treatment facilities required special seeding. True, it is possible to eventually adjust in nature the enzyme systems of these microorganisms. It has been found that if the enzyme systems and the microorganisms have been adjusted to several millions of generations, a reagent is produced that can be utilized, provided someone knows how to utilize it. I admit that there are many areas in which the applications of these microorganisms are not known.

The Dow Company, Midland, Mich., has, through 30 years of waste treatment, developed groups of microorganisms that are phenol and cyclical compound utilizing organisms of a high degree of adjustment.

A culture has been developed that utilizes petroleum oils. Many municipal sewage treatment plant digesters have trouble due to petroleum oil. These cities would have had to pay heavy costs for pumping out their digesters because they couldn't get enough actively digesting sludge to keep them operating. The organisms in the sludge would have had to adjust themselves to the hydrolysis of petroleum oil. We have taken preserved cultures and added them to these digesters with excellent results.

Unfortunately, in any new development the manufacturer is faced with so many problems and factors that he cannot always control the sale and proper application of his product. The amount of education that is required in this field is enormous. All of the companies presently engaged in this work are small. Efforts have been made to limit the number of specific applications which we think are economically important. Our product has not been sold for use in activated sludge. After many tests were made and tons of material were used in various plants, we found that the economic criteria in activated sludge was too delicate.

In sludge digestion, even an untutored operator can tell the difference between a badly acting, stinking digester and a good one, and he knows the difference by previous reference without having a controlled experiment. A sewage treatment plant operator or city manager knows that when the telephone stops ringing he has gotten a result. It is as simple as that, a telephone stops ringing and a result has been achieved because a nuisance has been corrected.

Professor McKinney:—One of the things that may have been misconstrued is the fact that at the Dow Chemical Co. there is a rather unusual type of organism, and it is an unusual condition to handle phenol waste. We have been working with the activated sludge breakdown of phenol wastes and the other cyclic compounds that appear in industrial wastes. In the metabolism of phenol, cresols, benzyl alcohol, benzoic acid compounds and the rest it has been found possible,

starting with domestic sewage, to develop activated sludge in less than a week that will handle those cyclic compounds. So, it is not difficult to find the organisms you want in sewage; the difficulty comes from adjusting the environmental conditions.

Professor Heukelekian:—What we are trying to do is tell the treatment plant operator that if he must develop a culture for destroying phenol, he can do it without buying something whose contents or phenol oxidizing ability are unknown to him. One of the speakers said that what is needed is more research, and that is what we are waiting for—proof.

Now, in regard to the use of marine sediments and the difficulties that are involved in terms of money to use them as seed material, I don't know why it is necessary to go to the marine sediments. Soil can be used if everything else fails, because soil harbors every kind of organism imaginable.

A. C. Bryan, Superintendent of Sewage Treatment, Houston, Tex.:—At Houston, Tex., some of these materials have been used and some have been quickly cast aside. Salesmen come in and they insist on applying some of the material, with no results. Firms in this business will make certain financial commitments to research through recognized institutions, and then when those commitments are followed up absolutely nothing is forthcoming.

Some products have certain benefits. As an illustration, we have a lagoon that is serving an overloaded plant. We do not like it, because it is located in a residential neighborhood and people call the city hall saying that it stinks. We had the fortunate experience of applying a biocatalyst and lo and behold, from the beginning the telephone stopped ringing. We are happy, because what more do we want? In another instance an overloaded digester was treated with a biocatalyst and started producing a good supernatant, and the sludge dewatered satisfactorily.

I do not like to call these materials biological catalysts because I do not know that they are catalytic. Catalysts do not enter into a reaction. Our experience has been that these materials must be added at intervals to maintain the benefits. Some of these biocatalytic materials are being used to advantage. How long that advantage will be maintained I don't know.

Glen Fortney, Sanitary Engineer, West Virginia State Department of Health, Charleston, W. Va.:—The West Virginia State Department of Health has approved one of the biocatalytic products now on the market. I am glad to see that some of the biocatalysts were discarded and others accepted. In the past year personnel of the health department have made some tests with a representative of one of the companies selling a biocatalyst. Although these tests were made on household type septic tanks, the results were poor. Out of eight tests, only two were found to have helped the situation. Since then the company has forwarded several letters reporting that this product had been in use in various treatment plants and had been used satisfactorily. I hope in the future we will be able to see more use of these products to determine just what the benefits are.

E. Sherman Chase, Partner, Metcalf and Eddy, Boston, Mass.:—I rise in defense of the academic viewpoint by making my favorite quotation from Aristotle. The quotation is this: "Ye who would know must first learn to doubt, for science is the solution of doubt."

GRIT CHANNEL EXPLOSION AT DANVILLE, ILLINOIS

By W. A. Hasfurther

Sanitary Engineer, Illinois State Sanitary Water Board, Springfield, Ill.

Two sharp explosions early on the morning of January 16, 1955, wrecked the brick building housing the comminutor and mechanical grit removal equipment at the Danville (Ill.) Sanitary District sewage treatment plant. Shortly before the first blast the operator had made a routine inspection of the building. The second explosion occurred before the operator was able to return to the building and fortunately no one was injured.

The explosive force completely removed the heavy roof constructed of concrete sections and covered with roofing paper (Figure 1). Almost all the windowpanes were blown out and several steel sash were bent as the windows were blown open. The walls cracked from floor to roof in the corners farthest from the inlet; the break passed through both the brick and mortar bond in a straight line. Slightly above the top of the windows and about two-thirds the way around the building there was a horizontal crack following the bond between two courses of brick (Figure 2). Apparently the wall above this break was lifted a fraction of an inch and then dropped back in place.

The sewer was vented to the atmosphere through a large open diversion and storm-water overflow box located 1,000 ft. upstream from the sewage treatment plant. Additional ventilation was provided at a manhole a short distance before the grit and screening building and a partially covered flow channel between this building and the main operation building. The second explosion damaged the manhole (Figure 3) and the diversion box so that the sluice gate in the latter structure could not be closed. Two heavy cast-iron manhole lids covered with more

FIGURE 1.—Damage to the roof and windows as a result of an explosion in the grit removal building, Danville, Ill., sewage treatment plant.

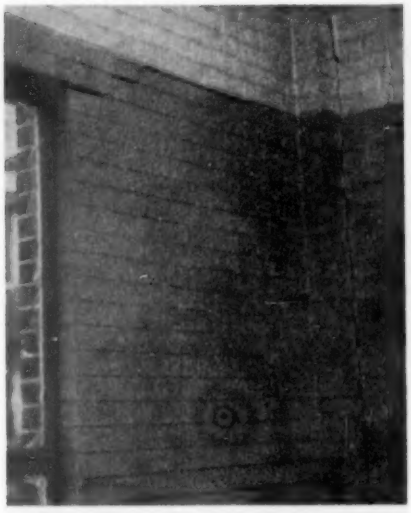

FIGURE 2.—Vertical and horizontal cracks in the brick wall of the grit removal building.

FIGURE 3.—Manhole damage on outfall sewer.

than a foot of dirt were forced off on the short line from the diversion box to the river. One of the covers landed 27 ft. from the manhole. The extent of damage to the sewer has not been determined.

Moisture condensation in the grit removal building always has been a serious problem, especially during the winter. The moisture necessitated frequent painting of the equipment and interior walls, particularly the steel roof trusses. A thorough scraping and painting job has been completed only last fall. Several unsuccessful attempts had been made to alleviate the moitsure problem by means of ventilation and boarding over the flow channels. Early in the winter a small coal burning heater was installed with a reasonable degree of success.

Shortly after the blasts, plant superintendent Frank Kohn and the Danville fire chief noted a strong odor of gasoline or a similar compound. By noon the odor was no longer present at the treatment plant, but an odor similar to that of naphtha or a solvent was noticed in the diversion box. No unusual odors were detected by investigators early in the morning in the sewers ahead of the diversion box. The municipality has the usual number of dry cleaning and other solvent using establishments. However, investigations to date have not uncovered the source of the solvent.

From the information available it appears that the explosions were caused by a considerable volume of volatile and explosive liquid discharged in a batch into the sewer. The vapors were very likely ignited by the coal heater, although an electric spark from a switch or motor also would have been sufficient.

Once again the record reveals that municipalities cannot afford to permit the indiscriminate use of their sewers. Authorities should make an early review of their local sewer ordinances and bring them up to date if they are lacking in either coverage or enforcement. Treatment plant personnel should be encouraged to check all sections of the plant for explosive hazards. Any unusual condition of the raw sewage should be immediately checked and an investigation made. Tomorrow might be too late!

TIPS AND QUIPS

Handy Reminder for Recurring Jobs

A solution on how to keep ahead of those periodic jobs that must be done on schedule appeared in a recent issue of *Public Works*.* After trying the obvious methods of memory and writing in a calendar pad, the author finally tried a series of oversized colored notes, which slip in between the pages of a desk calendar pad, or a diary or appointment book. Each note contains the instructions, a starting date or perhaps a completion date for the project, and a date on the bottom indicating where to place the slip in the calendar.

Much writing and rewriting in the calendar pad is avoided, and if the job cannot be started on the day the notice turns up, the slip is moved to the next day. After completion of a recurring periodic job, such as a quarterly report or inspection, the slip is moved ahead to the next reporting date. When action has been completed for the year, the slip is placed in the back of the calendar pad ready for the next year's program. It takes only a few moments to note the date on the bottom of the slip and place it in the pad or diary.

Try it today! It is an excellent supplement to the punch card maintenance system reported in the November 1954 Operator's Corner (page 1399).

Air Conditioning Via Paint

The scorching summer temperatures occurring in metal buildings, sheds, and other structures reportedly may be lowered as much as 45° through the application of a heat-repellent paint to the roof of the building. This "air-conditioning" paint reflects heat, light, and infrared waves from its white surface. The manufacturer advises that it has been applied successfully to steel, wood, aluminum, glass, asphalt shingles, and masonry. Further information can be obtained from A. Daigger and Co., Kinzie at Wells St., Chicago 10, Ill.

Digester Ventilator

Condensation in the floating cover of a digester frequently presents a problem through accelerated corrosion of the structural steel. The operators of two sewage treatment plants in Florida report good results in keeping the cover dry by installing a ventilator in the manhole lid. A hole 12-in. in diameter was cut in the lid. Into the hole was welded a 10-gage galvanized metal pipe 30 in. long. To the pipe top a rain-proof louvre cover was fastened. The cover was placed at the 30-in. height to obtain cross-wind ventilation even when the floating cover was low.

Greatest Resource

President Dwight D. Eisenhower made the following significant prediction at the recent National Rivers and Harbors Congress: "I have become convinced that before very long America will almost unanimously look upon water as its single greatest resource."

Potato Wastes

Industrial wastes from potato warehouses have long been a source of siltation in the public waterways of the State of Washington. In addition, the silt has been a general handicap to sewage treatment plants.

Sampling tests by the Washington Pollution Control Commission showed that 0.3 per cent of the total weight of

* Morris, J. L., "Keeping Account of Those Recurring Jobs." *Pub. Works*, **86**, 2, 101 (1955).

the potatoes cleaned at the warehouses is washed off as silt and organic material. In one warehouse discharging to a county drainage ditch, this represented slightly more than a ton of solids per day.

Radioactive Wastes

The most extensive single by-product of the manufacturing process at the G. E. Atomic Products Operation, Hanford, Wash., is radioactive liquid wastes. Costly facilities are required to insure its safe disposal because of the great potential health hazard.

Wastes from the uranium recovery plant are treated to form a precipitate that removes certain long-lived radioactive materials by carrying them down into a sludge at the bottom of the tank. The clarified solution is disposed of through absorption into the ground. It is understood that some radioactive wastes are disposed of by storage in large liquid-tight underground tanks.

Perhaps sewage treatment plant operators could do this with troublesome digester supernatant!

Calendar Sense

This year there will be an opportunity to support the proposed equal-quarter World Calendar. Many people do not realize how crippling our current calendar is. However, those who have had to plan budgets, make out work schedules or analyze data realize what a difficult proposition it is when there are seven combinations of the days of the regular months and 14 for February.

In the equal-quarter World Calendar, each quarter would have a month of 31 days and two months of 30 days each. The four quarters total 364 days. The extra day in each year would come at the end of December and would be called "World Day." The second extra day of a leap year would come at the end of June and would be another "World Day." World Days would be world-wide holidays, without date.

Use of the World Calendar would make it possible to compare sewage treatment plant operating data for one May with any other May instead of trying to compare a month of four Saturdays with one of five Saturdays. The idea is backed by many professional and business organizations. If action is taken now, a long-overdue end can be brought to a chaotic situation.

DDVP—A New Insecticide

A new insecticide, dimethyl dichloro vinyl phosphate, is more potent in killing insects and less toxic to humans and farm animals than many modern economic poisons. Highly volatile, DDVP is an organic phosphorus compound discovered by research scientists at the Savannah, Ga., laboratory of the U. S. Public Health Service. Due to its high potency, DDVP is expected to be most effective where flies and insects have developed a resistance to DDT.

Safety Equipment Identification

Easy identification of safety equipment eliminates much of the confusion that results when unexpected hazards occur in sewage treatment plant operations. To place the correct safety unit in the hands of emergency works in a matter of minutes, it is suggested that large block-type lettering be printed on chests or cabinets containing special safety equipment.

White letters on black or green letters on a light-colored background provide good legibility. Green color identifies safety and first aid equipment. Lettering on the walls above or alongside the equipment helps rescue workers spot the location.

Reviews and Abstracts*

Recovery of Soluble Gas and Aerosols from Air Streams. By E. M. Berly, M. W. First and L. Silverman. *Ind. Eng. Chem.*, **46**, 1769 (1954).

Waste air streams are scrubbed very effectively by fibrous materials which are wetted with a recirculating stream of water. The fibrous material may consist of glass, saran, or dynel. A very complete descriptive article includes modifications necessary for many different types of problems.

R. S. Ingols

Determination of Cyanides in Water and Waste Samples. By F. J. Ludzack, W. Allen Moore and C. C. Ruchhoft. *Anal. Chem.*, **26**, 1784 (1954).

This excellent article on the determination of cyanides indicates that the *n*-butyl alcohol extract of the pyridine-pyrazolone method is markedly superior to several other methods tested. The data show that the extracted color of pyridine-pyrazolone color compound is stable and has the best sensitivity. It forms over a wide range in original pH.

The conditions necessary for the release of bound cyanide (complex metal cyanide, such as the ferrocyanide ion) are reported. Specific rigorous conditions for obtaining total cyanides are reported.

R. S. Ingols

Wet Carbon Combustion and Some of its Applications. By D. D. Van Slyke. *Anal. Chem.*, **26**, 1706 (1954).

The techniques of carbon determination using sulfuric acid and dichromate are reviewed. However, the techniques discussed all use the measurement of carbon dioxide rather than the destruction of dichromate. It is indicated that some carbon is discharged into the gas phase as carbon monoxide instead of carbon dioxide. This may account for some error in the technique of measuring the organic matter by noting only the change in the dichromate concentration.

R. S. Ingols

Electrodialysis of Water Using a Multiple-Membrane Cell. By A. G. Winger, G. W. Bodamer, R. Kunin, C. J. Prizer and G. W. Harmon. *Ind. Eng. Chem.*, **47**, 50 (1955).

The basic principles of the multiple-membrane cell for reducing ion concentrations for potable water or industrial wastes are presented. The details of cell construction and a detailed discussion of the energy requirements capacity and effectiveness of treatment are given. This type of equipment should be useful for inorganic wastes where a reduction in the concentration of ions may solve the pollution problem.

R. S. Ingols

Concentration of Radioactive Aqueous Wastes—Electromigration through Ion-exchange Membranes. By W. R. Walters, D. W. Weiser and L. J. Marek. *Ind. Eng. Chem.*, **47**, 61 (1955).

A treatment of radioactive wastes is proposed. The first step involves partial decontamination in a multicompartment membrane cell of the same general type proposed for producing potable water from saline water. The second step involves decontamination in another multicompartment permselective cell modified with a mixed resin granular bed exchanger in the deionization compartments in order to remove the ions without the use of chemicals.

Power consumption is too high for a high degree of purity in the waste stream unless the mixed bed exchanger is used. The concentrated waste stream is then evaporated.

R. S. Ingols

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N. W., Washington 16, D. C.

A Summary of a Report, with Recommendations to the Chairman and Members on the Collection, Treatment and Disposal of the Sewage and Trade Wastes of the Auckland Metropolitan Drainage Area. By D. H. Caldwell, J. T. Calvert, C. G. Hyde, A. M. Rawn and Harold Wilson. Planograph, 104 pp. (July 1, 1954).

This is a report of a five-member board on the collection, treatment and disposal of the sewage and trade wastes of the Auckland Metropolitan Drainage Area in New Zealand.

The Drainage Board was established in 1908, and was finally modified in 1951. The area comprehended is about 205 sq. mi., with a total population of 296,200 (1951), of which 127,000 reside in the city of Auckland. The Board is responsible only for trunk sewerage and sewage disposal, and controls the discharge of sewage into the harbors in the area. However, pollution has crept in by reason of crude sewage and industrial wastes.

There are two main harbors, one (77 sq. mi.) relatively deep; and one (123 sq. mi.) shallow. In the former are 42 beaches, in the latter, 22, all of which are widely used.

Auckland is an industrial center, with a large proportion of dairy and food products. The topography is diverse and intricate. The geology is complex, due to volcanic conditions. The average rainfall for ten years (1944–1953) was 51.17 in., well-distributed.

The expected population is 420,000 (1960) and 800,000 (2000). The average water consumption in the decade 1944–53 ranged from 68 to 71 g.p.c.d.

The harbor waters are used for shipping, recreation, and shellfish culture (oysters, pipi, and scallops).

The sewage flow is assumed to be 50 g.p.c.d. in dry weather. Considerable storm water enters the sewer system. By 2000 A.D., the industrial wastes are expected to average 16.3 m.g.d., of which about 30% will be meat packing wastes.

Sewage disposal in the two harbors is complicated by the number of outfalls (14) and 250 sewer overflows in the main harbor, which has 42 bathing beaches. In the shallow harbor are at least 12 separate outfalls and 11 bathing beaches.

On March 11, 1954, work previously let to a French contracting firm was suspended because in the opinion of this Board the resulting project would be inadequate and the location of treatment works and outfalls unsuitable.

This Board outlines a comprehensive project for the entire Metropolitan Drainage District, with utilization of the shallow harbor for purification lakes, with a present cost of £7,247,700 and £1,700,700 for future work, a much cheaper solution of the problem than heretofore considered.

The proposed scheme is predicated on the use of sludge lagoons following primary sludge digestion and the concentration of treatment and disposal in one plant instead of seven.

The main features of the proposed treatment works are pre-aeration and grit removal tanks, sedimentation, sludge digestion tanks, sludge lagoons, auxiliary trickling filters, purification (oxidation) lakes with an outfall to operate only during ebbtide into an ample waterway.

Sewage effluent will be available as irrigation water and digester gas for electric generators operation.

An area of 70 acres is suggested for sludge lagoons, and 1,500 acres of existing mud banks for the purification lakes.

Langdon Pearse

Disposal of Sewage from Small Communities and Institutions. By Walter Dardel. *Jour. Inst. Sew. Purif.* (Brit.), 167 (1952).

This is a general review and discussion of the problems of rural and institutional sewage disposal, and the means presently available for treatment in small plants. In general the examples cited and the factors used are based largely on Swiss practice, although they are readily adaptable to local conditions elsewhere.

Among the types of installation discussed in detail are septic tanks, Imhoff tanks, plain sedimentation tanks, digestive tanks, trickling filters, intermittent sand filters, oxidation ponds (lagoons), land treatment, subsurface irrigation, and sub-surface filters.

The article should be read together with the same author's article on "Septic Tanks and Other Small Sewage Treatment Works in Switzerland" (see World Health Org. Monograph Series No. 18, p. 85).

Langdon Pearse

Electrolytic Regeneration of Spent Pickling Solutions. By H. C. Braner and J. Coull. *Ind. Eng. Chem.*, **47**, 67 (1955).

Results are presented of a laboratory study of a proposed process for the electrolytic regeneration of spent sulfate pickling solutions. The process makes use of selectively ion permeable membranes to separate the solution from the recovered acid so that iron deposition can occur in a low acid medium. The recovered acid can be re-used in the pickling operation.

R. S. Ingols

Phenol Sorption on Ion Exchange Resins. By R. E. Anderson and R. D. Hansen. *Ind. Eng. Chem.*, **47**, 71 (1955).

Data are presented on the recovery of phenol and chlorinated phenols from strongly acid solutions. The quaternary ammonium anion exchangers have a good capacity for the ionic removal of phenol plus a nonionic adsorption capacity of almost equal amount. The phenol is removed by stripping the resin with a sodium hydroxide methanol solution. The phenol can then be recovered from the methanol by distillation and the solvent re-used.

R. S. Ingols

Anion Exchange Removal of Iron from Chloride Solutions. By A. C. Reents and F. H. Kahler, *Ind. Eng. Chem.*, **47**, 75 (1955).

It has been found that a pure hydrochloric acid solution can be produced by passing the concentrated, commercial grade acid through a column of quaternary-type anion exchanger. This same idea has been studied for the removal of iron for regenerating hydrochloric acid used in iron pickling baths: it holds the promise of reducing the amount of acid for disposal. R. S. Ingols

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This pier-supported collector is designed for circular tanks. The rotating bridge acts as the lever arm rotating a sturdy center cage which carries the collector arms. Rotational force is provided by a two-wheeled, rubber tired tractor unit running on the rim (or effluent weir wall of the tank). Drive unit is simple, easily accessible, and not affected by snow or ice.

SUSPENDED COLLECTORS are used where a simple bridge can span the tank diameter. In this case, the complete motor and drive assembly, together with the drive tube and collector arms, are suspended from the bridge.

WRITE FOR BULLETIN 9W65

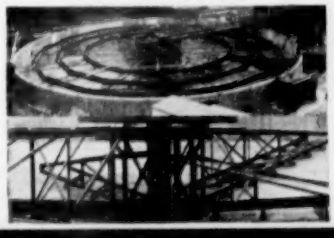
CLARIFLOW THICKENER

This unit utilizes the principles of fluid mechanics, so highly developed in Walker sedimentation units. It removes all settleable solids and remarkably clarifies the flow. All parts are sturdily built . . . designed for the "tough" jobs.

WRITE FOR BULLETIN 10169

PIER DRIVE COLLECTOR

The Pier Drive Collector is recommended where it is undesirable to operate a Tractor Drive . . . where the access bridge must be stationary, or the corners of square tanks must be scraped. Center drive mechanisms, ranging from 1/2 to 10 horsepower, are built for long life and heavy duty service. Worms are carburized and ground steel and precision meshed with hardened bronze worm wheels. The balls run in hardened, ground, renewable ball races.



WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.
Factory — Engineering Offices — Laboratories
Aurora, Illinois

Proceedings of Member Associations

NEBRASKA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 3rd Annual Meeting of the Nebraska Sewage and Industrial Wastes Association, held at the Keystone Hotel, McCook, Nebr., on November 11–12, 1954, attracted a record registration of 43 persons.

Among the papers presented at the meeting were the following:

"Progress in Sewage Treatment in Nebraska," by T. A. Filipi, Division of Sanitation, Nebraska State Dept. of Health, Lincoln.

"Care and Maintenance of Sewage Pumps," by G. Strudgeon, Chicago Pump Co., Chicago, Ill.

"Things to Know about Lime," by R. M. Slater, Ash Grove Lime and Portland Cement Co., Omaha.

"Lubrication and Maintenance," by E. Baxter, Continental Oil Co., Lincoln.

"Iowa Program of Voluntary Operator Certification," by H. S. Smith, Stanley Engineering Co., Muscatine, Iowa.

"Landscaping of Sewage Treatment Plants," by W. C. Whitney, Dept. of Horticulture, University of Nebraska, Lincoln.

"Shone Pneumatic Sewage Ejector," R. C. Gloppen, Yeomans Brothers Co., Melrose Park, Ill.

"Coil Filter Vacuum Sludge Dryer," by O. F. Barklage, Omaha.

"Chlorination of Sewage," by J. B. Burke, Fischer & Porter Co., Hatboro, Pa.

(*Continued on page 200a*)

SNOW GATES
for
SEWAGE TREATMENT PLANTS

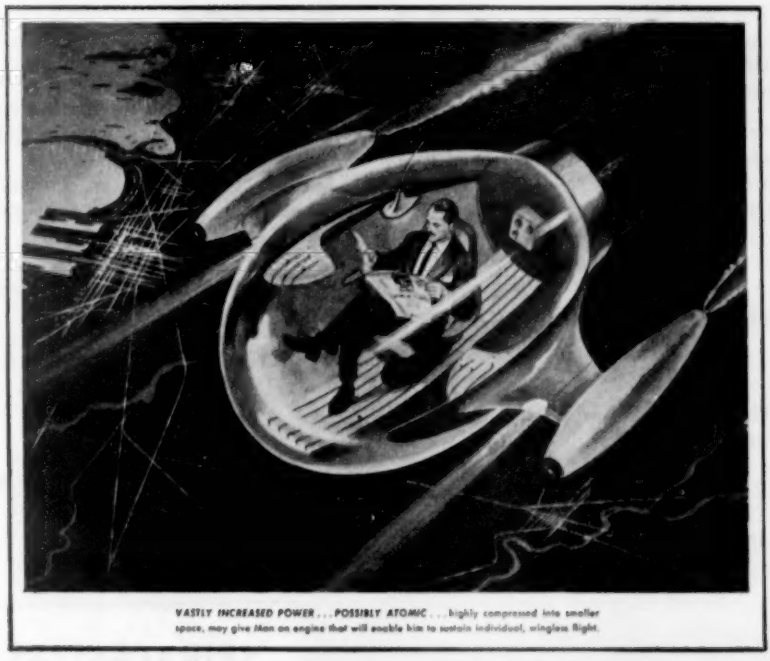
All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

SNOW GATES & VALVES
2437 East 24th Street Los Angeles 54, Calif.



VASTLY INCREASED POWER . . . POSSIBLY ATOMIC . . . highly compressed into smaller space, may give Man an engine that will enable him to sustain individual, wingless flight.

100 years from now...

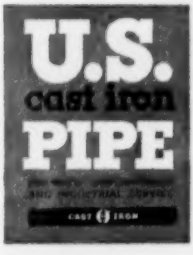
WE MAY "FLY LIKE THE BIRDS"

Time and the future will reveal many wonders...

But in that Jules Verne-like world of tomorrow you'll find one familiar note: water and gas will still be carried by the dependable cast iron pipe laid today.

Throughout the nation, records show that over sixty American cities still use cast iron water and gas mains laid more than a century ago. No pipe can match cast iron's demonstrated longevity. And today, U. S. Pipe, centrifugally cast, is even stronger, tougher, more durable.

U.S. Pipe is proud to be one of the leaders in a forward-looking industry whose service to the world is measured in centuries.



U. S. PIPE AND FOUNDRY COMPANY, General Office: Birmingham, Alabama

A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE.

"The McCook Sewage Treatment Plant," by Paul W. Mousel, Consulting Engineer, McCook.

The last paper was followed by an inspection trip to the McCook plant.

Officers elected for the ensuing year were as follows:

President: E. E. Borden, Hastings.
Vice-President: W. F. Rapp, Jr., Crete.
Secretary-Treasurer: V. J. Lechtenberg, Omaha.

V. J. LECHTENBERG,
Secretary-Treasurer

SOUTH CAROLINA WATER AND SEWAGE WORKS ASSOCIATION

The Annual Business Meeting of the Sewage Section, South Carolina Water and Sewage Works Association, was held at the Jefferson Hotel, Columbia, S. C., on March 18, 1955.

Officers were elected as follows:

Chairman: F. M. Gibson, Greenville.
Vice-Chairman: R. G. Pennington.
FSIWA Director: E. D. Fry, Greenville.
Secretary-Treasurer: T. A. Kolb, Columbia.

W. T. Linton was nominated to receive the Federation's Arthur Sidney Bedell Award.

Action also was taken to enlarge the meetings to include appropriate technical programs.

T. A. KOLB,
Secretary-Treasurer

NEW ENGLAND SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 26th Annual Meeting of the New England Sewage and Industrial Wastes Association was held on Oc-

(*Continued on page 202a*)

A 20 ft. dia. Spiragester
ST. PARIS, OHIO

SPIRAGESTERS are IDEAL for:

Population equivalents of 5500 or less, whether for schools, hospitals, resorts, certain trade wastes, small communities or subdivisions.

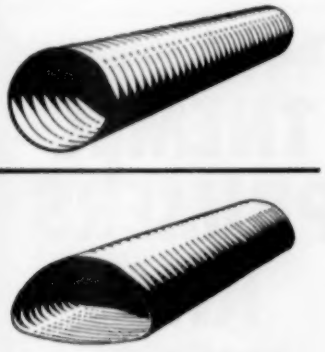
A visit to one of the many Spiragester installations will reveal a lack of odors and unsightliness.

•

Write for Bulletin 135

Lakeside Engineering Corporation
222 West Adams St., Chicago 6, Ill.

ARMCO SEWER STRUCTURES



have the erosion and corrosion resistance you need!

With most types of sewers it's a case of "take it or leave it," as far as erosion or corrosion resistance is concerned. But with Armco Sewer Structures, you can select the degree of protection warranted by your installation. You meet corrosion and erosion hazards efficiently and economically.

The basic Armco Sewer Structure is either Armco Corrugated Metal Pipe or Pipe-Arch. The Pipe is supplied in diameters from 8 to 96 inches; Pipe-Arch span-and-rise dimensions range from 18 by 11 to 72 by 44 inches. All are supplied in gages from 16 to 8, depending upon size.

HOW MUCH PROTECTION DO YOU NEED?

Galvanized Armco Corrugated Structures meet normal sewer requirements.

Asphalt Coating provides additional protection against corrosion.

PAVED-INVERT Sewers resist erosion damage in the structure invert.

Asphalt Coated PAVED-INVERT Structures are used to combat the combined hazards of corrosion and erosion.

ASBESTOS-BONDED Sewers are specified for severe corrosive conditions.

ASBESTOS-BONDED PAVED-INVERT Sewers give you maximum protection against the combination of severe corrosion and erosion.

Write us for more data on Armco Sewer Structures and recommendations on your specific sewer problems. Armco Drainage & Metal Products, Inc., 5215 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.

ARMCO®

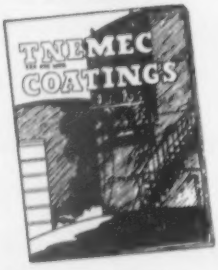
It's simple chemistry...

TNEMEC PRIMERS KILL RUST!

From acid (rust) condition to alkaline (NON-RUST) condition in one easy step with

TNEMEC PRIMERS!

HOW?



TNEMEC CATALOG 54 TELLS THE STORY!

A request on your business letterhead will bring you this very useful Catalog 54.

TNEMEC
TEE-NEE'-MEK
"Spell It Backwards"

TNEMEC COMPANY, INC.
135 W. 23rd Ave., North Kansas City, Mo.

tober 28, 1954 at the Patterson Club, Fairfield, Conn. The one-day meeting was well received, with an attendance of 178.

The meeting was held in concurrent sessions, with one devoted to operation and the other to research.

Papers presented at the Research Session were as follows:

"Metabolism of Simple Alcohols by Activated Sludge," by Prof. R. E. McKinney and John S. Jeris, Department of Civil and Sanitary Engineering, Massachusetts Institute of Technology.

"Some Revised Concepts Regarding Biological Treatment," by John P. Wold, Sanitary Engineer, USPHS, and John D. Frame, Research Engineer, Metcalf & Eddy, Boston, Mass.

"Algae Problems in Lake Zoar and Pilot-Plant Studies for Control of Nuisance Blooms," by S. Lane Wilson, Biologist, Conn. Agricultural Experiment Station, and John J. Curry, Chief Engineer, State Water Commission of Connecticut.

"Statistical Analysis of Coliform Data," by Prof. H. A. Thomas, Jr., Division of Applied Sciences, Harvard University.

Papers presented at the Operation Session were as follows:

"Design and Construction of Improvements to the Norwalk, Conn., Sewage Treatment Plant," by Edwin B. Cobb and John P. Marr, Partner and Project Engineer, Metcalf & Eddy, Boston, Mass.

"Operation of the Norwalk, Conn., Sewage Treatment Plant," by Joseph Perry, Superintendent.

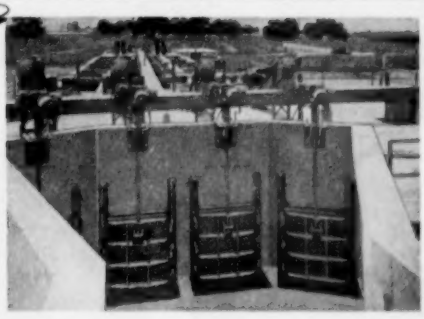
"Pressure Joints for Vitrified Clay Pipe," by John R. Masterson, Clay Sewer Pipe Association, Columbus, Ohio.

"Design and Construction of the Fairfield, Conn., Sewage Treatment Plant," by John G. Albertson, Part-

(*Continued on page 204a*)

Plan with Quality...

Pekrul



4-36" Pekrul model 45A Sluice gates at Sacramento Sewage Treatment plant

City managers...engineers... contractors...know that the precision engineering and quality construction of Pekrul Gates means a *planned* water control project that will fulfill its purpose. It costs no more to plan with quality...specify Pekrul Gates on your *next* project.

PEKRUL GATE DIVISION

Write on your letterhead for NEW Pekrul Gate Catalog No. 55

MORSE BROS. MACHINERY
DENVER, COLORADO

MANUFACTURERS OF PEKRUL GATES FOR

Flood Control · Sewage Disposal · Rearing Ponds · Recreation Pools
Levees · Reservoirs · Irrigation · Cooling Towers · Pumping Plants
Water Works · Oil Refineries · Steel Mills · Dams · Fish Hatcheries

Surer Gland Lubrication
for Centrifugal Pumps

THE Z-F GREASE SEAL

Eliminates that trouble spot where shaft enters casing. Applies constant positive lubrication to packing and shaft—automatically. Excessive heat, rapid wear, leakage and scoring will disappear as the Grease Seal supplies a constant flow of lubrication when pump starts until it stops—automatically. Many other advantages, too. Write for complete description and price.

Zimmer and Francescon, Moline, Ill.

ner, Bowe, Albertson & Associates, New York, N. Y.

"Operation of the Fairfield, Conn., Sewage Treatment Plant," by William C. Henry, Superintendent.

Officers elected for 1955 were as follows:

President: W. E. Merrill, Boston, Mass.

1st Vice-President: J. H. L. Giles, Hartford, Conn.

2nd Vice-President: C. N. Sawyer, Cambridge, Mass.

Secretary-Treasurer: H. F. Munroe, Cranston, R. I.

Assistant Secretary-Treasurer: E. R. Howard, Hartford, Conn.

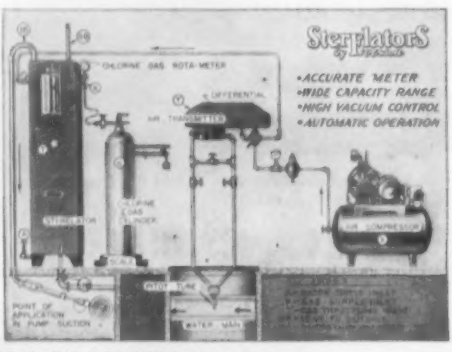
The afternoon program was devoted to inspection tours of the Fairfield and Norwalk sewage treatment plants.

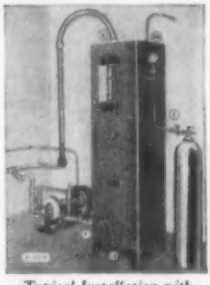
STEPHEN M. HURLEY,
Secretary-Treasurer

Sterilators by Everson

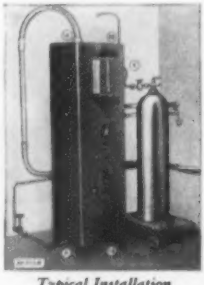
CHLORINE CONTROL APPARATUS
VACUUM SOLUTION FEED

AIR-O-MATIC SYSTEM





Typical Installation with Booster Pump on Water Supply



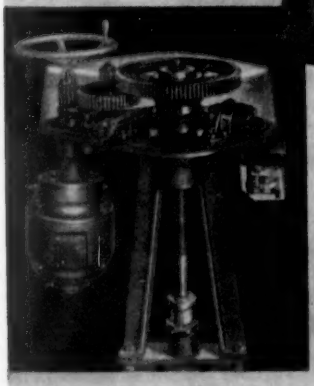
Typical Installation Showing Scale

AUTOMATIC PROPORTIONING
GAS FEED TO LIQUID FLOW

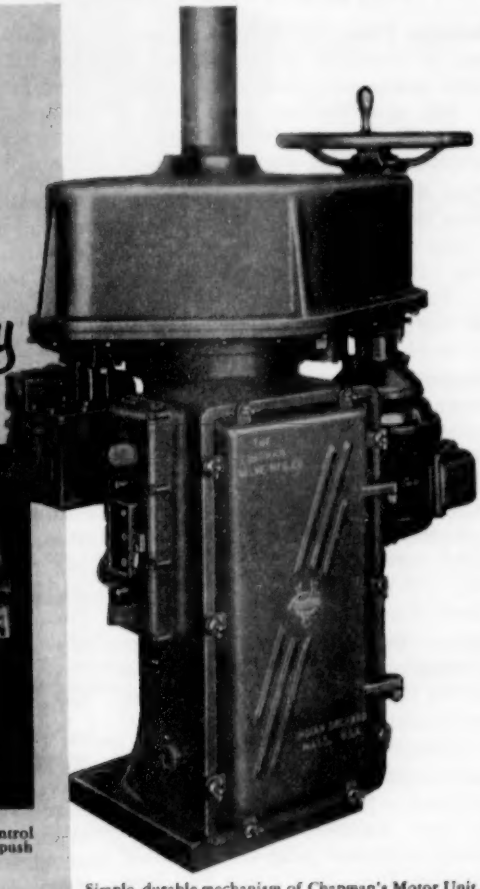
Everson Manufacturing Corporation
207 W. Huron Street Chicago 10, Illinois
REPRESENTATIVES IN PRINCIPAL CITIES

Fewer Parts Mean

Greater Dependability



Floorstand Motor Unit . . . control panel, motor, limit switch and push button station.



Simple, durable mechanism of Chapman's Motor Unit. Handwheel remains stationary during motor operation.

IN CHAPMAN MOTOR UNITS

Chapman's simple and rugged Motor Unit gives accurate, trouble-free control of large valves and sluice gates. It has approximately *half as many parts* as any other unit. Its simplified design, low speed motors and low-ratio, stubtooth gears combine to give positive operation without drift, in *any* position and under all conditions.

Installation is fast and simple. The floorstand unit comes completely wired, ready to connect to leads. Limit switch has micrometer adjustment for exact presetting for seating tightness. Motor Units operate smoothly under the most adverse conditions. All units are weatherproof and steam-tight. Write today for *new* Catalog 51.

The Chapman Valve Manufacturing Co.

INDIAN ORCHARD, MASSACHUSETTS

Equipment and Supply Lines

Sewage Plant Devices—The many types of company products used in sewage treatment plants are described and full specifications are given in 20-page Bulletin C–5200.—Rockwell Manufacturing Co., Pittsburgh 8, Pa.

Pipe Surface Thermometers—New surface thermometers to fit ½-in. to 2-in. pipes and tubes snap in place with spring clips to eliminate opening joints for installation.—Pacific Transducer Corp., 11836 W. Pico Blvd., Los Angeles 64, Calif.

Magnetic Flow Meter—Technical Information Leaflet 27–A–71a gives complete specifications and engineering data on new electromagnetic flow meter designed for 2-in. to 8-in. pipelines. Advantages claimed are noninterference by pressure, viscosity, density, corrosiveness or conductivity of the flowing liquid.—Foxboro Co., Foxboro, Mass.

General Catalog—New 12-page general catalog lists and gives specifications for complete line of process instrumentation.—Fisher & Porter Co., 172 Jacksonville Rd., Hatboro, Pa.

Lubricated Plug Valves—New 40-page Catalog No. 5 gives complete details and specifications on Teflon gasketed lubricated plug valves.—ACF Industries, Inc., 30 Church St., New York 8, N. Y.

Laboratory Ovens—Gravity and mechanical convection laboratory ovens and sterilizers, together with accessories, are described in new Catalog A.—Modern Laboratory Equipment Co., 1809 First Ave., New York 28, N. Y.

Laboratory Apparatus—Various bulletins detail and illustrate laboratory apparatus, instruments, and materials.—A. Daigger & Co., 159 W. Kinzie St., Chicago 10, Ill.

Flotation System—Bulletin 54–82 describes complete flotation treatment system for water, sewage and trade wastes.—Chain Belt Co., Milwaukee 1, Wis.

Multiple Recorder—New 12-page brochure (Product Spec. El 2–5) gives specifications for receiver-recorder for pneumatic and electric transmission systems.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

Synthetic Filter Cloth—Engineering data on selection of filter cloths for filtration or dust collection are gathered in a new 6-page folder on Feon cloths.—Filtration Engineers, Inc., 155 Oraton St., Newark 4, N. J.

Laboratory Dryer—New portable self-contained laboratory dryer unit has either manual or automatic control.—C. G. Sargent's Sons Corp., Graniteville, Mass.

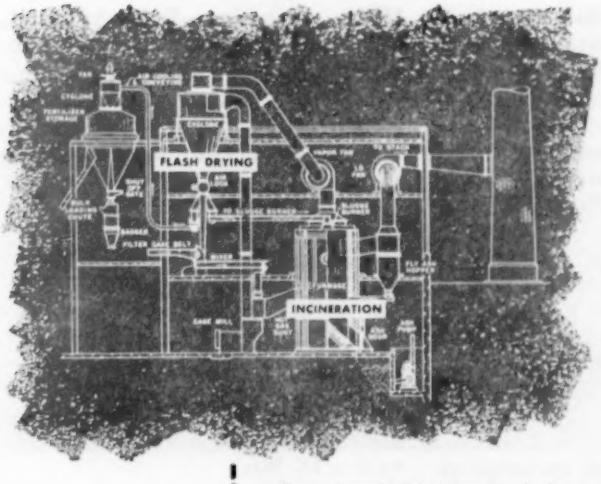
Instrument Pen—New instrument recording pen fed from a plastic ink sac reduces instrument attention time and gives long service.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

Non-Clog Solids Pump—New "Torque-Flow" solids pump utilizing a revolutionary concept of centrifugal materials handling is described in Bulletin No. SP–10 and other releases. Manufacturer claims new principle reduces abrasive wear and unit does not damage even tender fruit in liquid flow.—Western Machinery Co., 760–766 Folsom St., San Francisco 7, Calif.

Chlorinator Automatic Proportioner—Catalog 70–20 describes and gives specifications for an automatic proportioning unit for use with chlorinators.—Fischer & Porter Co., 160 Jacksonville Rd., Hatboro, Pa.

Evaporator—Concentration of wastes is described in a bulletin outlining the advantages of combined thermal compression and evaporation units.—Roots-Connersville Blower Div., Dresser Industries, Inc., Connersville, Ind.

(*Continued on page 208a*)



SOME FACTS ABOUT THE HEAT DISPOSAL of SEWAGE SLUDGE

Even though dried sewage sludge can often be sold at from $5.00 to $20.00 a ton — remember that is not *always* the case.

If sewage is contaminated — with grease, fibre, etc., for example — you may find the *only* thing to do is to incinerate the sludge. On the other hand, even though the sludge may not have the highest chemical analysis for fertilizer — it still can be marketed as a soil conditioner — thereby eliminating the ash disposal problem.

The C-E Raymond System of Flash Drying and Incineration is the most popular . . . most versatile on the market today. That's why you will find a C-E Raymond System to provide one or all of the following processes . . . controllably, accurately, economically:

1. **Flash Dry sludge.**
2. **Flash Dry and Deodorize.**
3. **Flash Dry and Incinerate.**
4. **Flash Dry, Incinerate and Deodorize.**
5. **Incinerate only.**
6. **Incinerate and Deodorize.**
7. **Flash Dry and Deodorize in conjunction with refuse and garbage incineration — plus incineration of sludge if desired.**

C-E Raymond Systems now in service or on order serve an equivalent population of more than 17,000,000 people — in communities ranging from 6,000 to 3,600,000 in population . . . in every section of the country, and even overseas.

Whatever your requirements — there is a C-E Raymond System that will satisfy them precisely. Let one of our engineers show you or your consultants how this leading system of sludge disposal will work for you.

B-772A

COMBUSTION ENGINEERING

Raymond Division

1315 North Branch Street, Chicago 22, Illinois
Eastern Office: 200 Madison Ave., New York 16, N. Y.
Western Office: 510 W. Sixth St., Los Angeles 14, Calif.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

Temperature Controller—New indicating temperature controller useable with remote probe is described in bulletins.—Fenwal, Inc., Ashland, Mass.

Anti-Rust Paints—New Bulletin No. 4591C describes complete line of Overust anti-rust paints.—The Chem Industrial Co., 3784 Ridge Rd., Brooklyn 9, Ohio.

Two-Stage Pumps—A new series of two-stage pumps for clear liquids in capacities up to 1,000 g.p.m. is designed to give operating efficiency and ease of maintenance.—Dept. SI, Goulds Pumps, Inc., Seneca Falls, N. Y.

Flotation Unit—New bulletin describes applications and specifications for new air flotation unit.—Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.

Flexible Pipe Coupling—New flexible steel coupling for pipe of 24- to 96-in. diameter is described in brochure.—R. H. Baker & Co., 2070 East Slauson Ave., Huntington Park, Calif.

Pipe Tapping—New manual gives step-by-step instructions on how to tap concrete pressure pipe without service interruptions—Price Brothers Co., 1932 East Monument Ave., Dayton 1, Ohio.

Proportioning Pump—Bulletin AP–54 describes a new type proportioning pump with no packing, unique high-speed valves, and pulse-free flow.—Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.

Chemical Balances—Theory and operation of single-pan laboratory balances are contained in Bulletin FS–207.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

General Instruments Catalog—Bulletin DM035 lists and illustrates complete line of recording, automatic controlling, and telemetering instruments.—The Bristol Co., Waterbury 20, Conn.

Emergency Generators—Bulletin EG 754 describes emergency power generators ranging from 2,000 to 15,000 w. in size.—Katolight Corp., 1st Ave. at Chestnut, Mankato, Minn.

Electrical Conduit—Heavy-duty rigid steel electrical conduit is especially designed to resist the severely corrosive conditions found in sewage works.—National Electric Products Corp., Gateway Center, Pittsburgh, Pa.

Generator Sets—New 8-page Bulletin G–6 describes generator sets using alternate fuel systems permitting use of natural or manufactured gas, gasoline, or sludge gas as fuel. Generator capacities range from 50 to 350 kw.—Le Roi Division, Westinghouse Air Brake Co., 1706 S. 68th St., Milwaukee 14, Wis.

Regulating Devices—Bulletin No. 2 describes 12 basic valve types used in control applications of automatic regulators.—Atlas Valve Co., 280 South St., Newark 5, N. J.

Butterfly Valves—Tight-closing, rubber-seated butterfly valves are described in Bulletin 650–L1.—Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

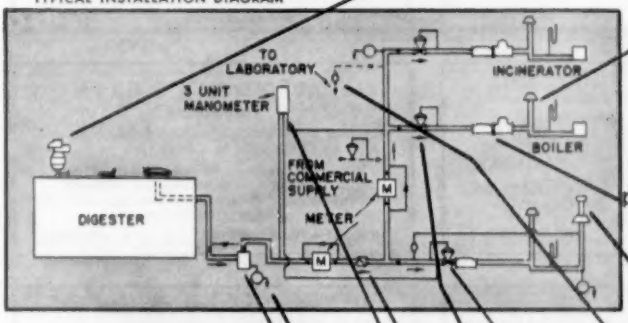
Temperature Transmitter—Measurement and transmission of process temperatures between —100° and + 1,000° F. are functions of a new instrument of the nonindicating type.—The Foxboro Co., Foxboro, Mass.

Titrimeter—Amperometric titration using a new accessory to the Elecdropode, a manual polarograph, is described in new literature. The speed and sensitivity of the method are based on the unit's rotating platinum micro-electrode.—Fisher Scientific, 717 Forbes St., Pittsburgh 19, Pa.

Control System—Remote transmission systems for control of plant processes are described in 8-page Bulletin 9100.—Automatic Control Co., 995 University Ave., St. Paul 4, Minn.

Electrical Controls—Watertight and explosion-proof electrical controls for pumps are described in new bulletins.—Gemco Electric Co., 25681 W. 8 Mile Rd., Detroit 19, Mich.

TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve — Fig. 70 — Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly — Fig. 450 — Prevents flame propagation in piping.

"VAREC" Waste Gas Burner — Fig. 236, 237 or 238 — Efficiently burns all excess gas.

"VAREC" Flame Check — Fig. 51A or 52A — Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly — Fig. 440 — Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator — Fig. 187 — Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve — Fig. 211 or 211A — Controls direction of gas flow.

"VAREC" Manometer — Fig. 215, 215A, 216 or 216A — Indicates system pressures.

"VAREC" Drip Trap — Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

Plan with "Varec" Symbols of Safety

FOR GAS CONTROL THROUGHOUT YOUR SEWAGE TREATMENT PLANT

"Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA, U. S. A.

S-10 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*

DIRECTORY OF ENGINEERS

(Continued through page 215a)

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WATER, SEWAGE AND INDUSTRIAL WASTE PROBLEMS
AIRFIELDS, REFUSE INCINERATORS
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CITY PLANNING — VALUATIONS
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